Remote Sensing
Chapter 1

Richard Christopher Olsen

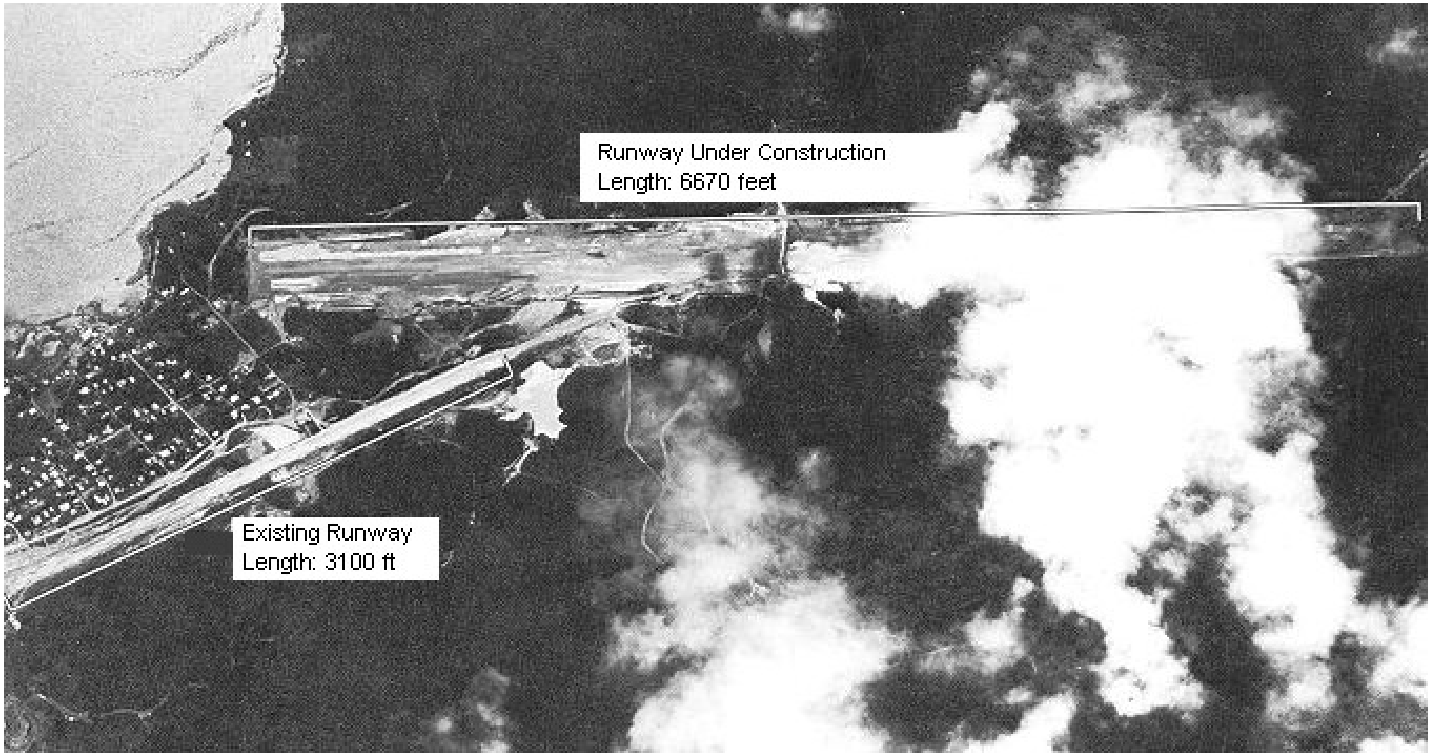
Remote Sensing

- Remote sensing began when Gaspard Felix Tournachon, known by his pseudonym Nadar, photographed a French village from a balloon. He took this aerial photo of Paris in 1867. (Image courtesy of USGS: Earthshots.

Order of Battle

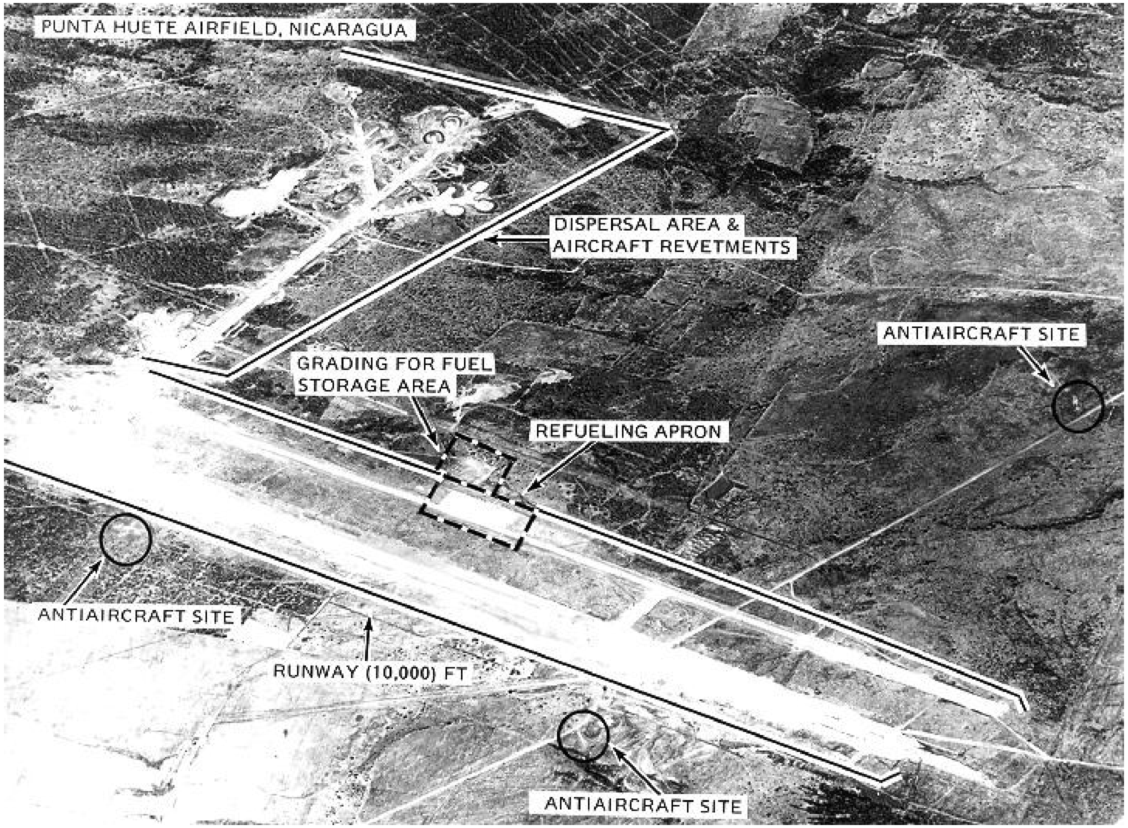
- Organization scheme for the course – OOB
  - Naval Order of Battle (NOB)
  - Air (AOB)
  - Electronic (EOB)
  - Industrial (IOB)
  - Space (SOB)
  - Ground (GOB)

Air Order of Battle



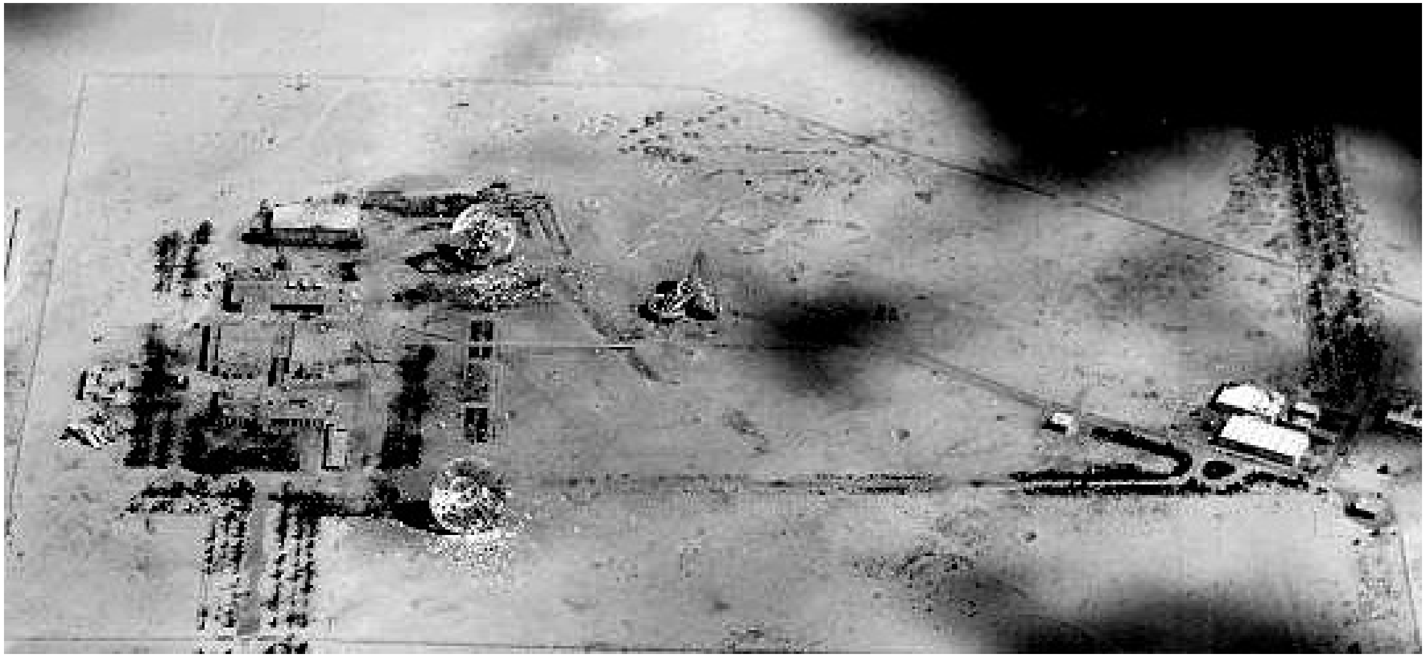
SR-71 image, Bluefields, Nicarauga, new runway under construction, 2 January 1982.

AOB-2



SR-71 image, Punta Huete Airfield, Nicarauga.

Electronic Order of Battle

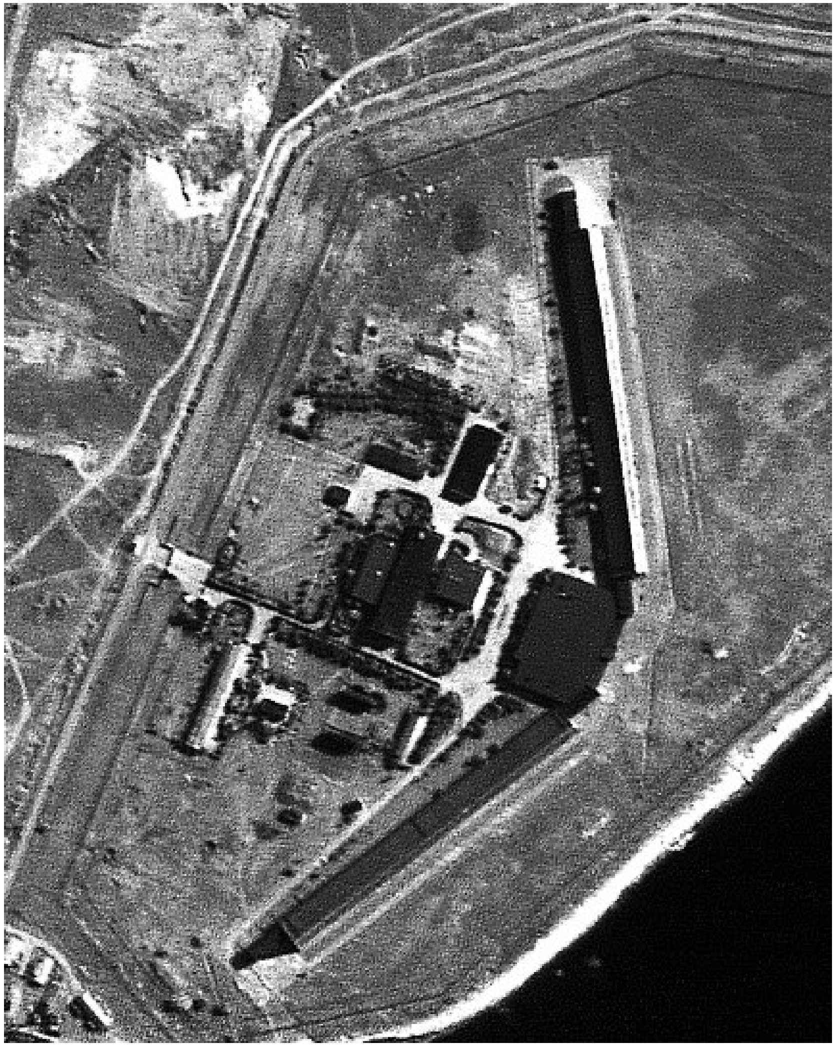


TARPS, (Tactical Airborne Reconnaissance Pod System) Umm al Aysh SATCOM

EOB-2

KH4 Corona image - Sary Shagan Operational Hen House Radar

EOB-3



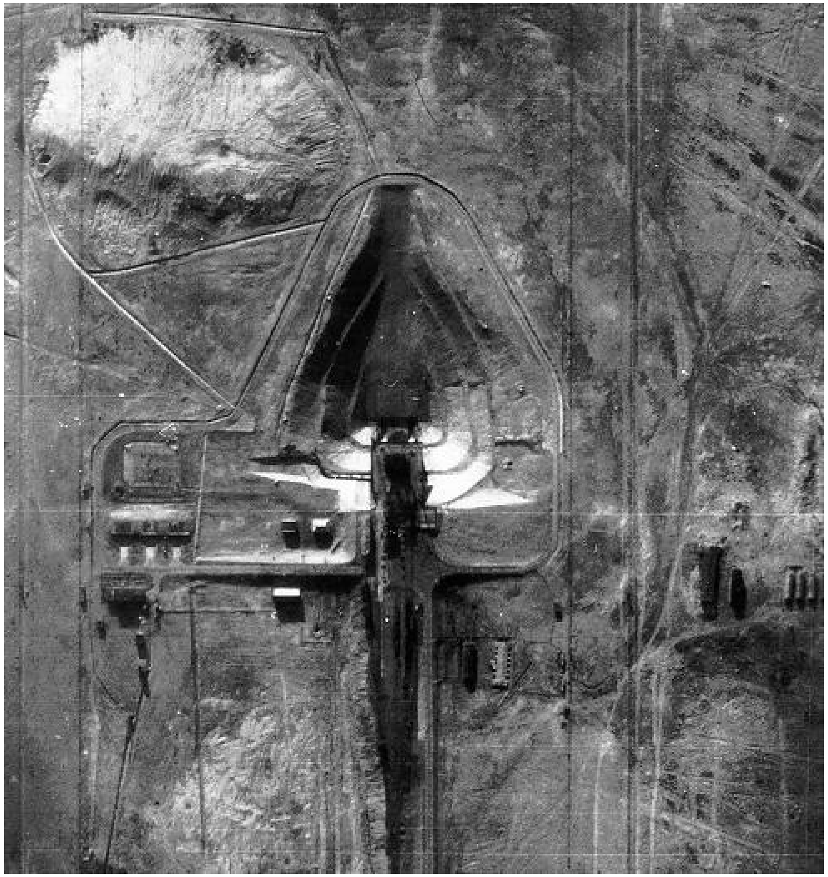
Early Warning Radar, Sevastopol Ukraine

Hen House Radar

EROS - October 12, 2002

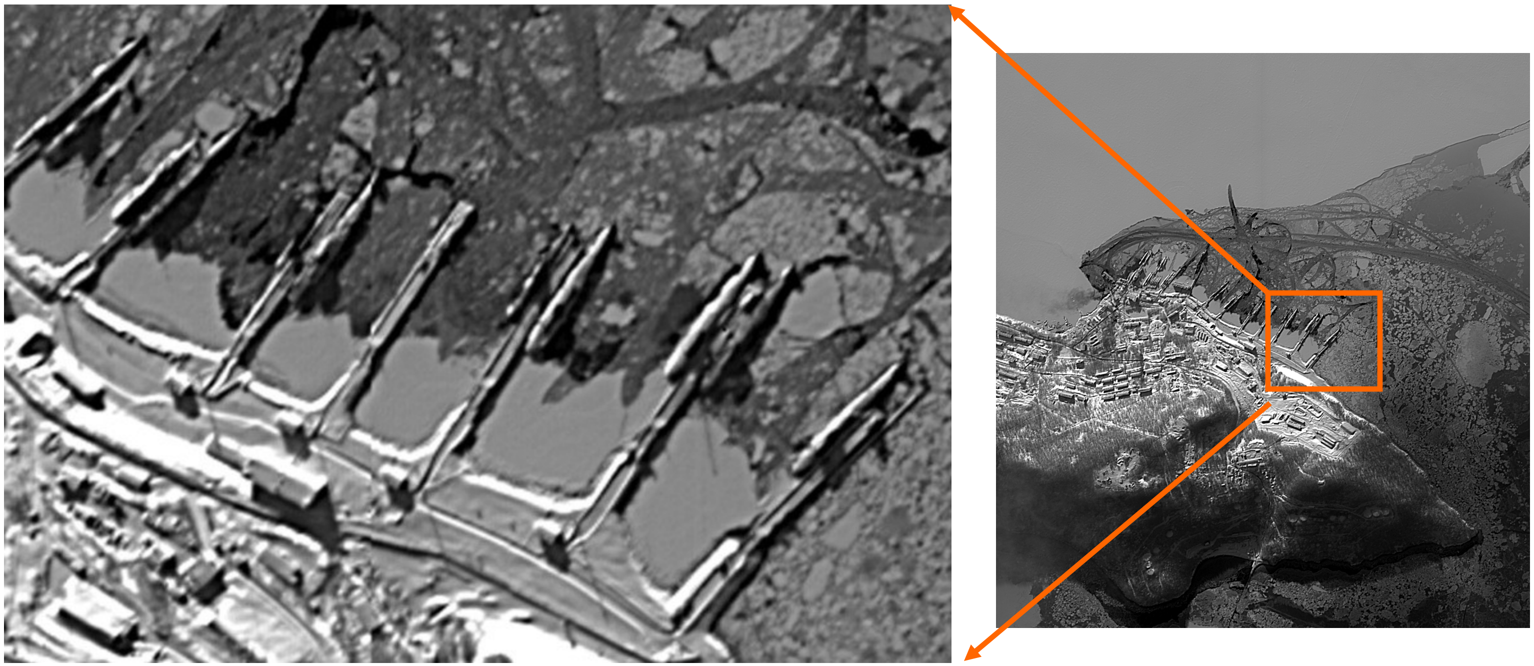
(See Notes)

Space Order of Battle



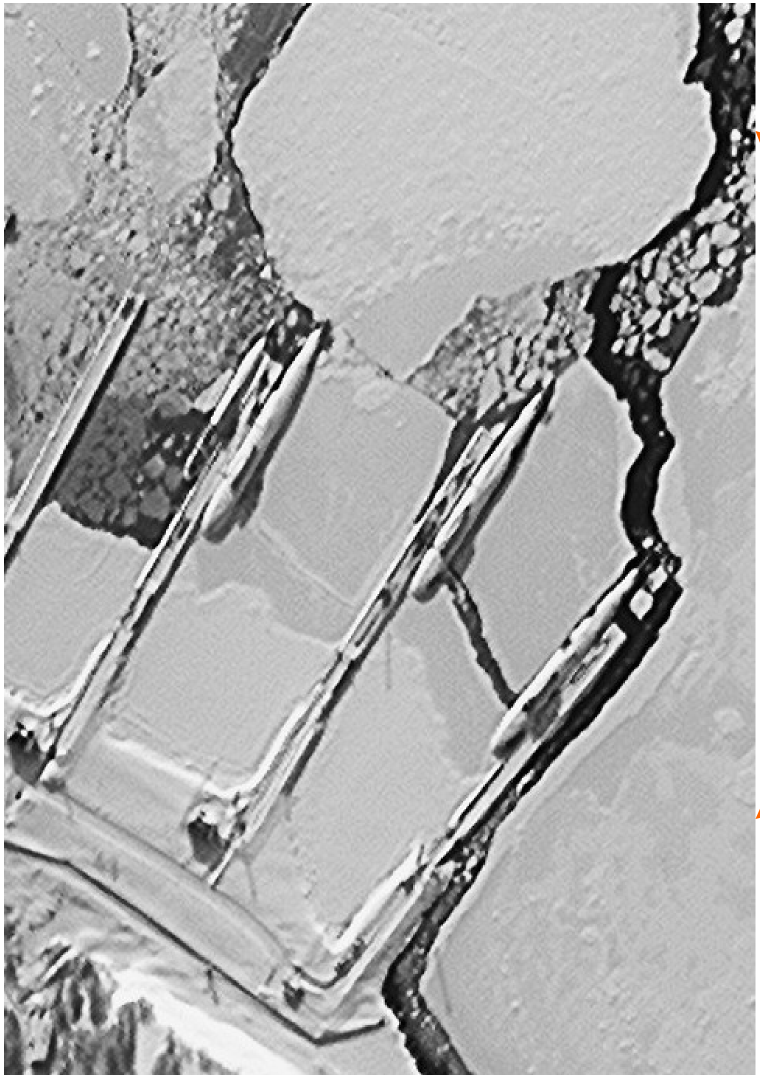
U2 image of SS-6 / Sputnik Launch Pad, Baikonur

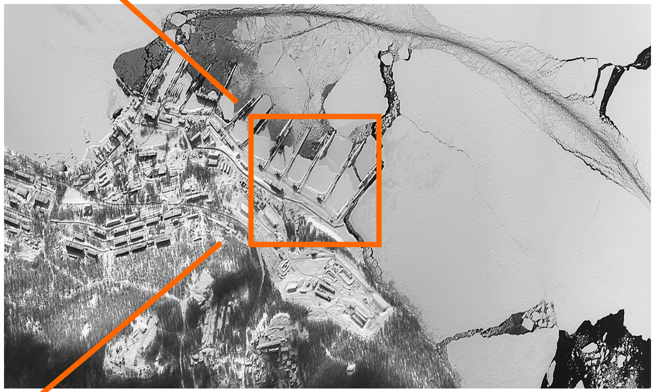
Naval Order of Battle



Kamchatka Submarine Base, Russia
EROS December 25, 2001
1.8 meter resolution
(See Notes)

Naval Order of Battle





Petropavlovsk-Kamchatka, Russia
EROS February 7, 2004
1.8 meter resolution

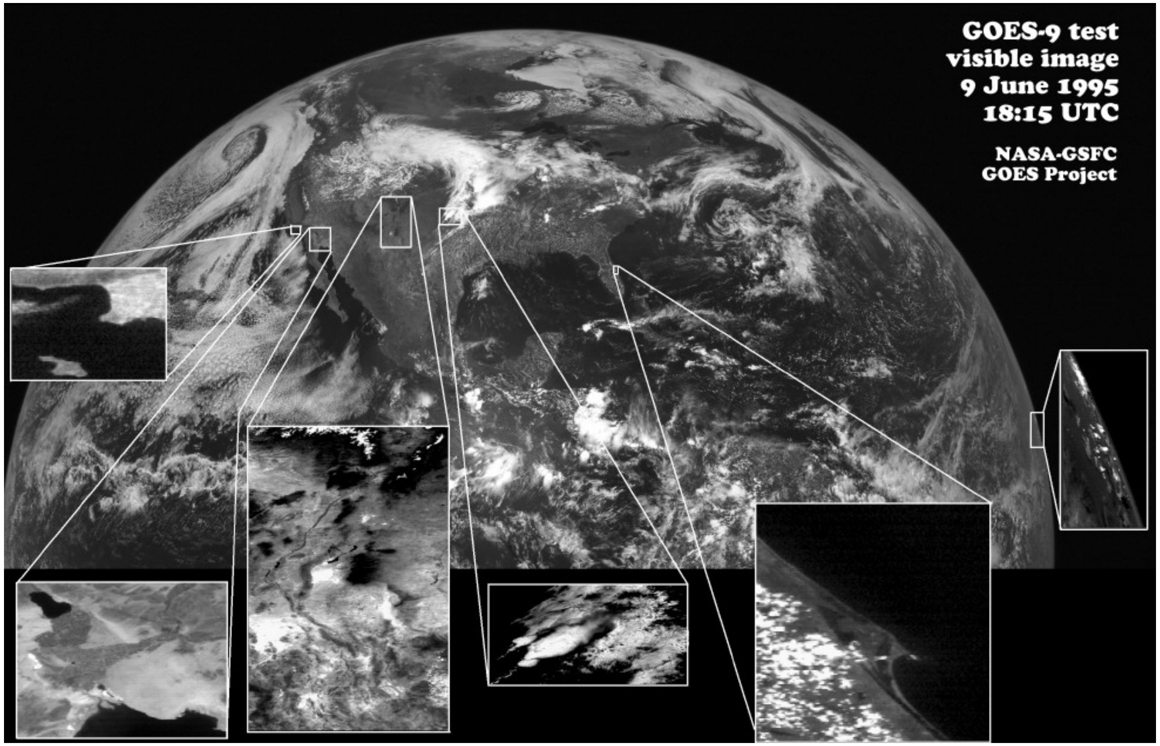
(See Notes)

Naval Order of Battle

IKONOS San Diego – February 7, 2000
1-meter resolution

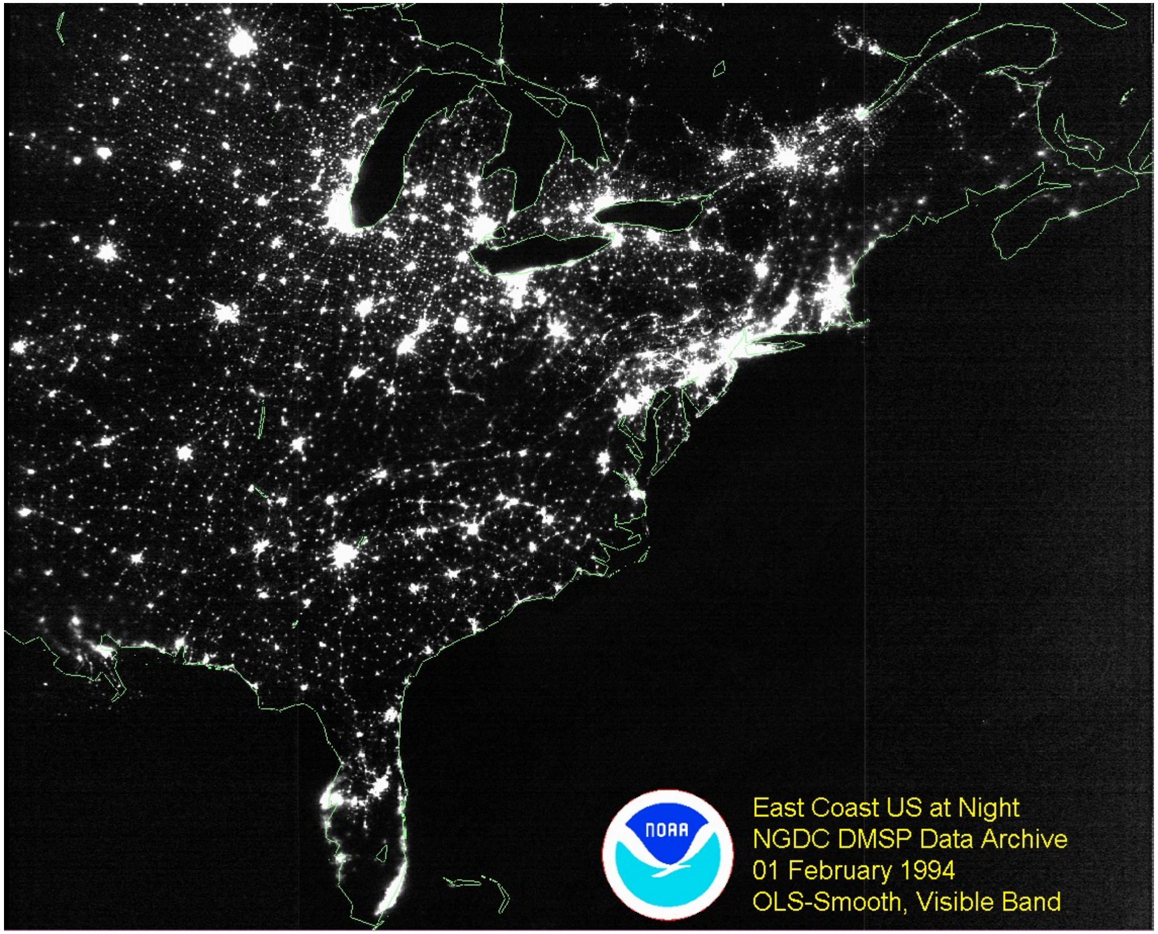
GOES

Global view – 1 km resolution



Geosynchronous orbit, full earth scan every 30 minutes

DMSP – City Lights



- Polar orbiting satellite, ~1000 km altitude
- Views strips of the earth, revisits ~ daily

Surrey Satellite Technology Ltd

- Spin-off from the University of Surrey ECE dept.
- They are doing what Orbview would like to do – making money by building and flying small satellites.
- TMSat – this was an early one - $2M on orbit
- 100 meter resolution
- San Francisco Bay - 29 August 1998 at 18:54:15 UTC

SURREY SPACE CENTRE

UoSAT-12

32-metre 4-band multispectral image

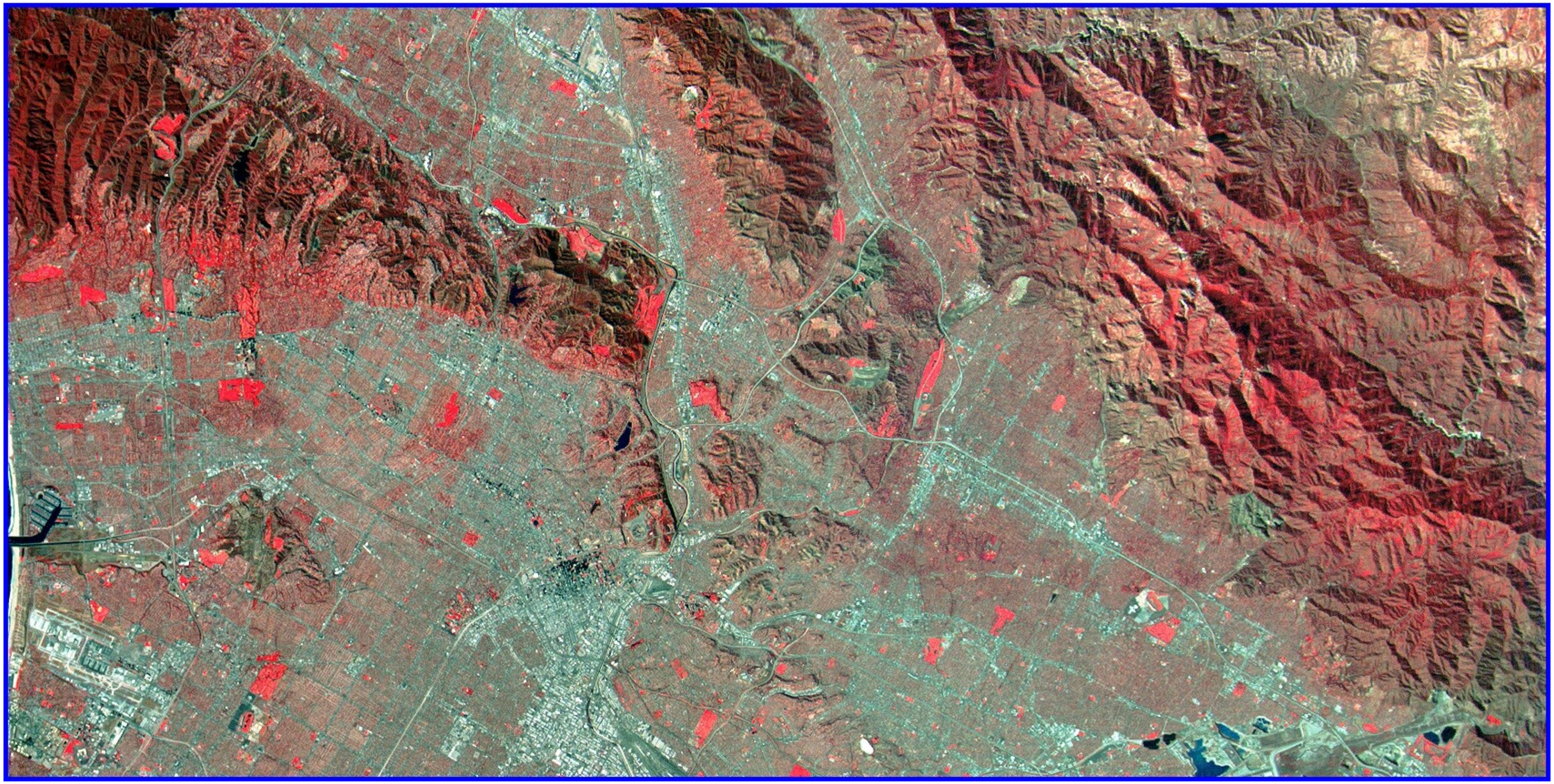
Los Angeles, USA
01 Feb 2000 at 20:54:21 UTC
(Bands 1, 2, 3)

SURREY
SPACE CENTRE

UoSAT-12

32-metre 4-band multispectral image

Los Angeles, USA
01 Feb 2000 at 20:54:21 UTC
(Bands 2, 3, 4)



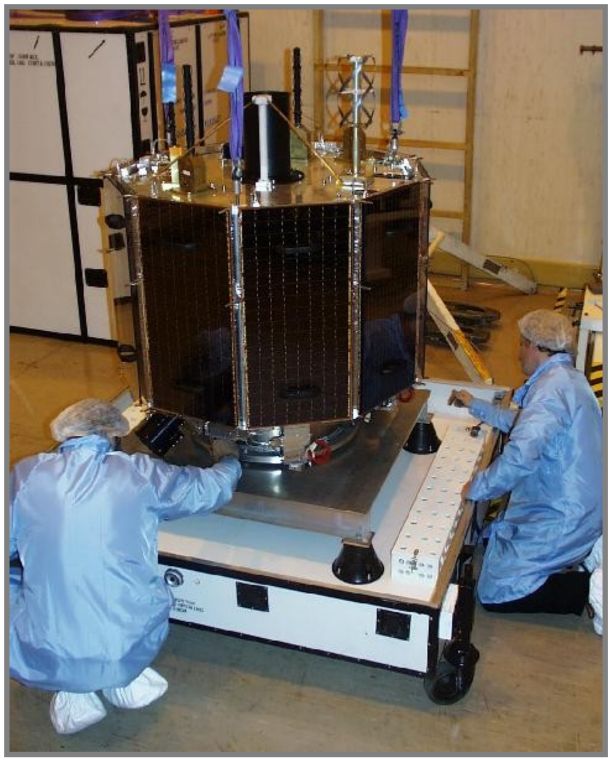
UoSat-12 Pan

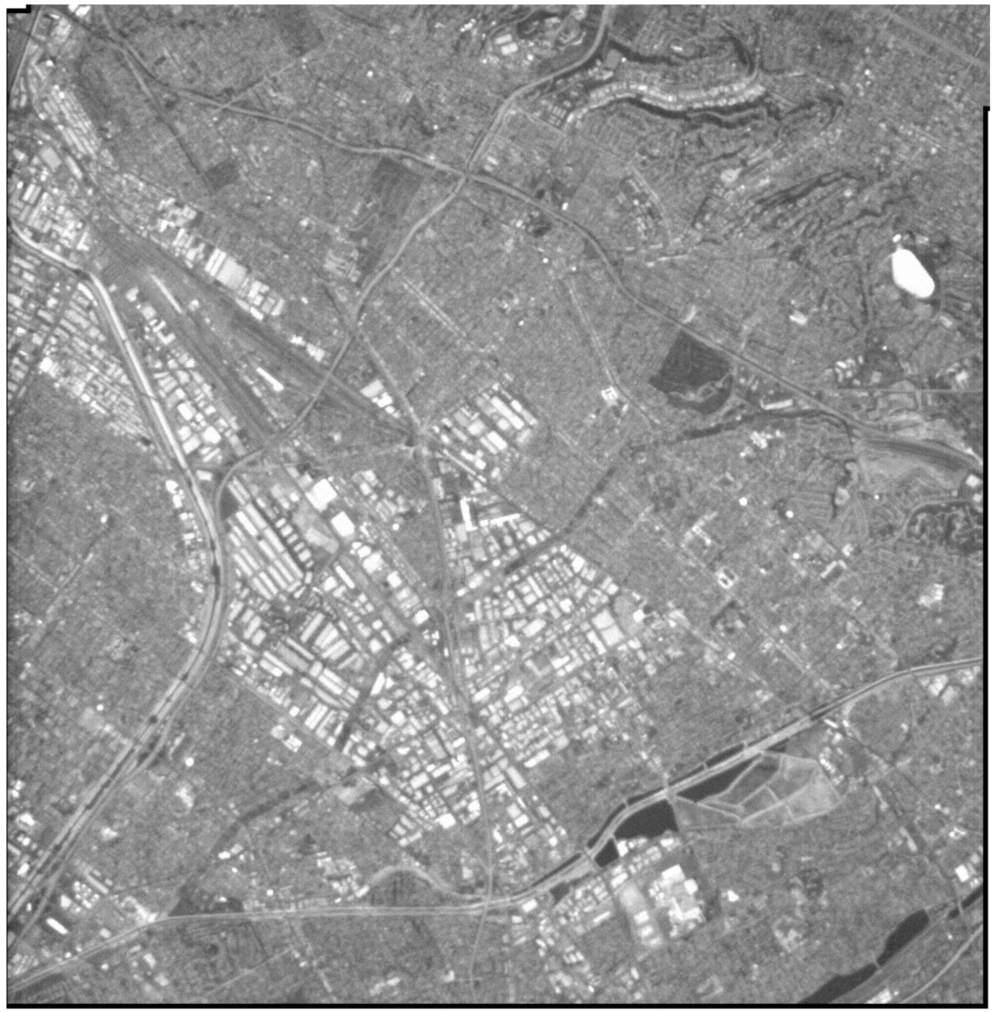
SURREY SPACE CENTRE

UoSAT-12

10-metre panchromatic image

Los Angeles, USA
01 Feb 2000 at 20:54:21 UTC





Univ. of Surrey

- Dr. Martin Sweeting has been knighted for his work with small satellites.
- In fact, the Queen has visited their labs.
- Please understand that in a clean room, you always have to wear a ‘bunny suit’, and a plastic cap.

Professor M.N. Sweeting,

Centre for Satellite Engineering Research,University of Surrey,
Guildford, Surrey GU2 7XH, UK

Univ. of Surrey

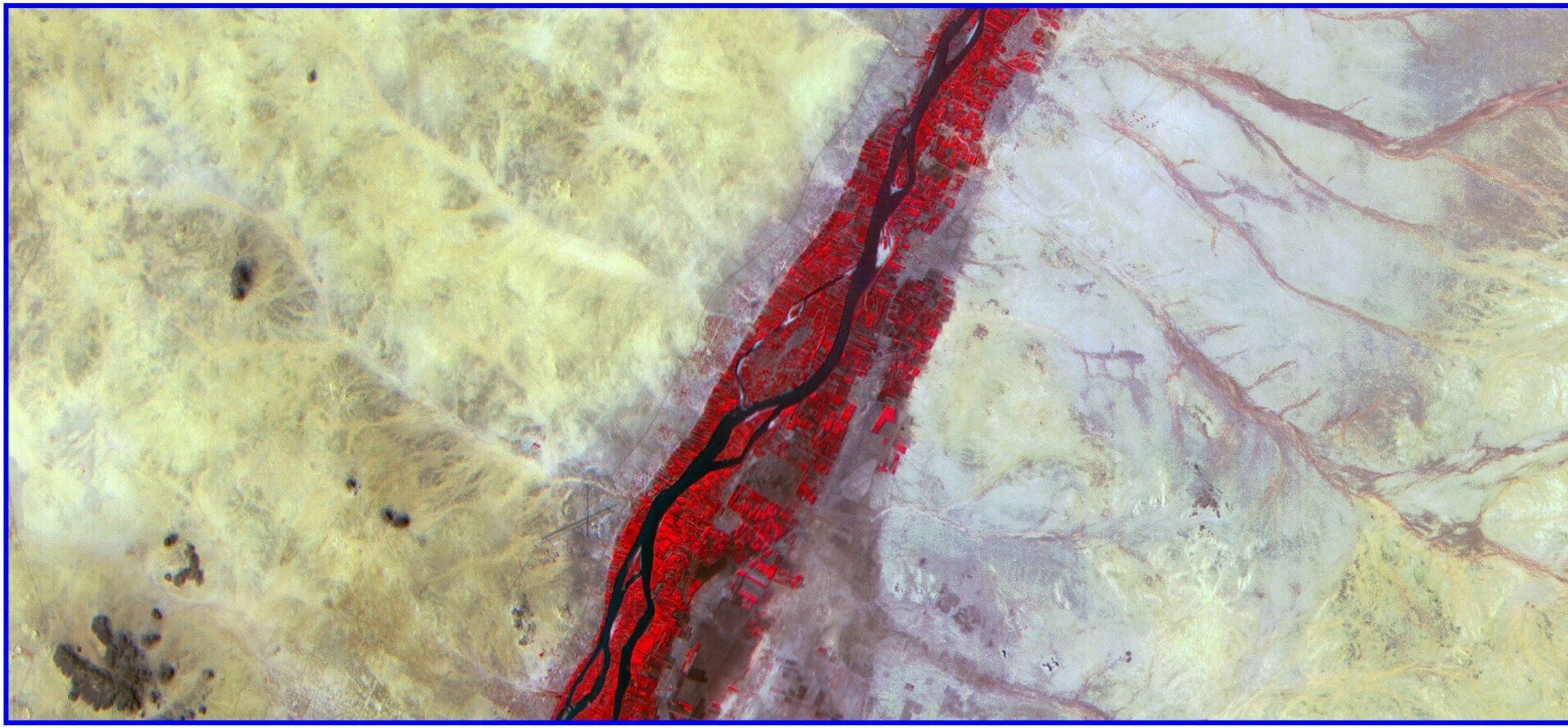
- Please understand that in a clean room, you always have to wear a ‘bunny suit’, and a plastic cap.
- Oh, and no purses.

SURREY SPACE CENTRE

UoSAT-12

32-metre 4-band multispectral image

Khartoum, Sudan
28 Jan 2000 at 12:45:26 UTC
(Bands 2, 3, 4)

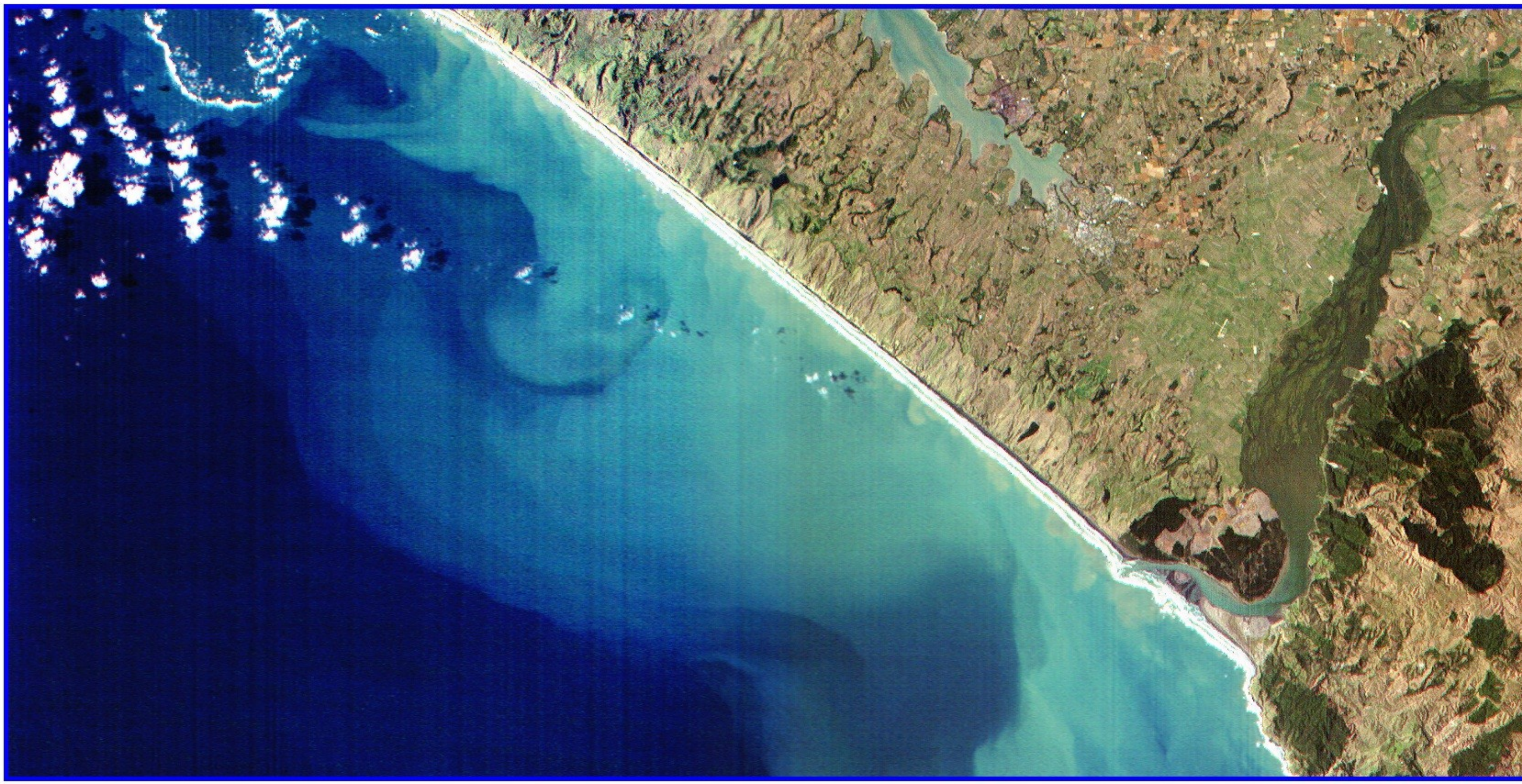


SURREY SPACE CENTRE

UoSAT-12

32-metre 4-band multispectral image

Waikato River, New Zealand
09 Mar 2000 at 03:29:25 UTC
(Bands 1, 2, 3)



UoSat and Technology Transfer

- UoSat sells satellites and the technology to other countries
  - Turkey just launched their first UoSat – 27 Sep 2003. BILSAT-1 offers 32-m spatial resolution

The world's first small satellite constellation dedicated to monitoring global disasters has been launched by British company, Surrey Satellite Technology Ltd. Three further satellites for Surrey's Disaster Monitoring Constellation were launched into low Earth orbit today, 27 September 2003, at 06:11 GMT onboard a Kosmos launcher from Plesetsk in northern Russia. The satellites, for Nigeria, Turkey and the UK, will join AlSAT-1, another Surrey-built satellite, launched for Algeria last November. Together they will transform the ability of international disaster relief organisations to monitor and provide emergency assistance to disaster-stricken zones whenever and wherever they occur.

The imaging capability of the DMC spacecraft is remarkable, scanning an area 600km x 600km – ten times that available from any other commercial satellite in orbit. Another first, the constellation can re-image any scene on Earth within 24 hours. Currently the best re-imaging capability from any commercial satellite in space is just once every 16 days.

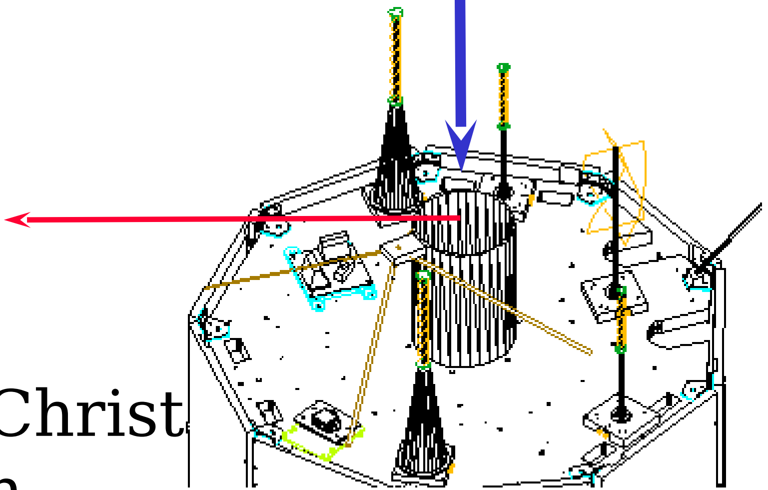
Today has seen the successful launch of:

BILSAT-1 for Turkey (Tubitak-ODTU Bilten)
NigeriaSat-1 for Nigeria (National Space Research & Development Agency)
UK-DMC (UK Government-funded)

SSTL UoSAT-12 Remote Sensing

High Resolution Panchromatic Imaging

- **10 metre GSD**
- **10 km swath**
- **1024 x 1024 pixels staring array**



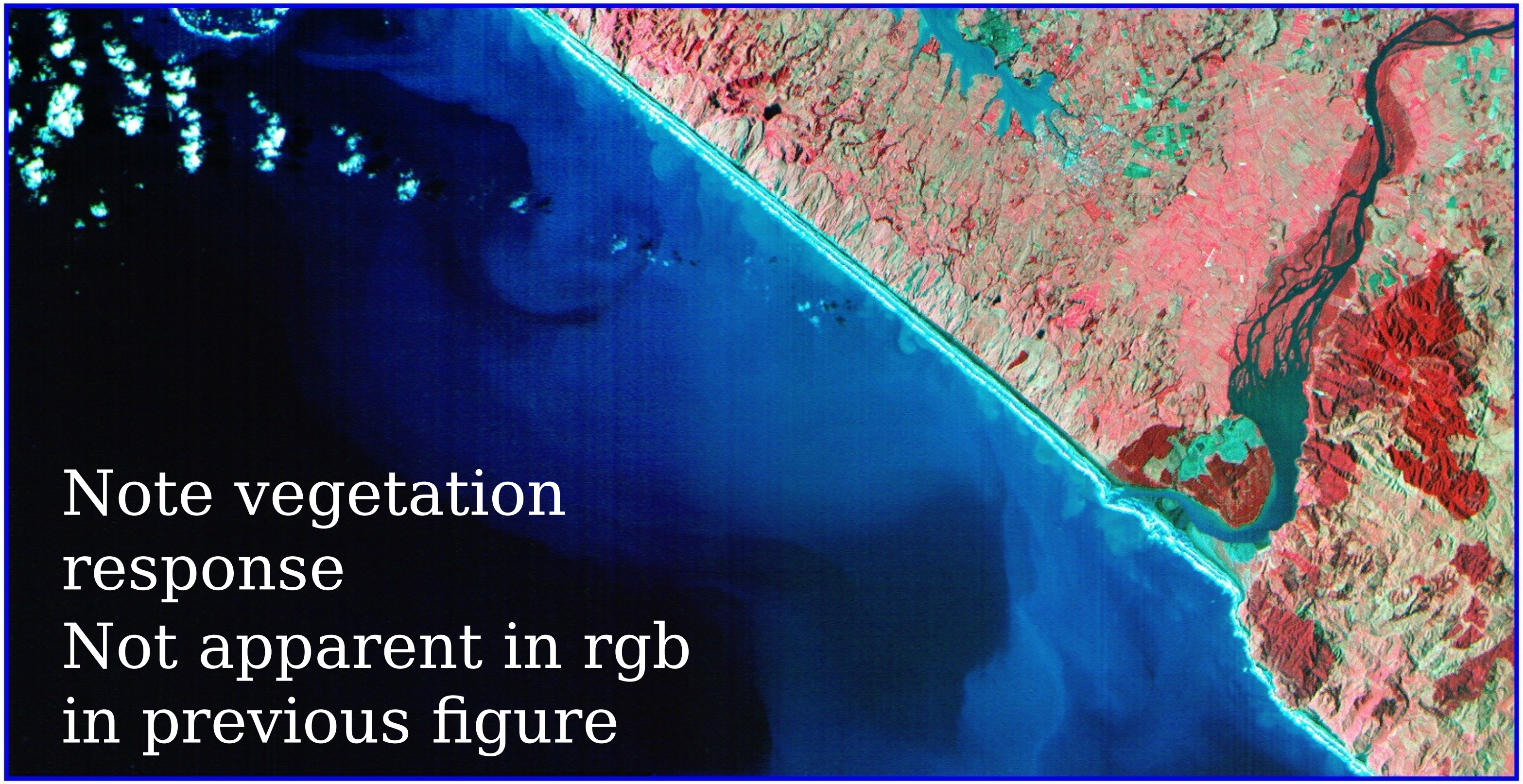
Christ

SURREY SPACE CENTRE

UoSAT-12

32-metre 4-band multispectral image

Waikato River, New Zealand
09 Mar 2000 at 03:29:25 UTC
(Bands 2, 3, 4)



Scary Future

- For higher resolution products, SSTL is working with top payload suppliers around the world. The TopSat satellite will provide 2.5 metres GSD from a sophisticated lightweight camera developed by Rutherford Appleton Laboratories. The DMC+4 satellite will carry a 4-metre GSD imager developed by SIRA electro-optics.

SURREY
SPACE CENTRE

UoSAT-12

32-metre 4-band multispectral image

Cape Canaveral (Fl), USA
05 Mar 2000 at 15:29:00 UTC
(Bands 1, 2, 3)

Landsat 5

LANDSAT 5 - 7 May 1996

- The standard for remote sensing of the environment for 30 years.
- 6 reflective (color) bands at 30 meter spatial resolution, one thermal band (120 or 60 meter resolution, depending on the bird)
- Revisits once every 15 days

L5 – Coronado

AOB – you can tell quite a bit about the airfield. You can tell if the carriers are tied up at their normal docks.
You can ‘see’ the Coronado bridge, because long linear features can be inferred even when they are ‘sub-pixel’

Gemini 11 - 09/14/66

What can a man see from space?

Near East area as seen from Gemini 11 spacecraft during its 26th revolution of the earth. The United Arab Republic (Egypt) is in foreground. Triangular-shaped area is the Sinai Peninsula. Saudi Arabia is at upper right. The Mediterranean Sea is at upper left. The Gulf of Suez separates Egypt from the Sinai Peninsula. The Red Sea is at bottom right. The Gulf of Aqaba is body of water in right center of photography separating the Sinai Peninsula and the Arabian Peninsula. The Dead Sea, Sea of Galilee, Jordan and Israel are in top center of picture. Iraq is at top right edge of photograph.

Space Shuttle

This image was selected to show because the shuttle was at an unusually high altitude for this mission, and has a correspondingly large field of view

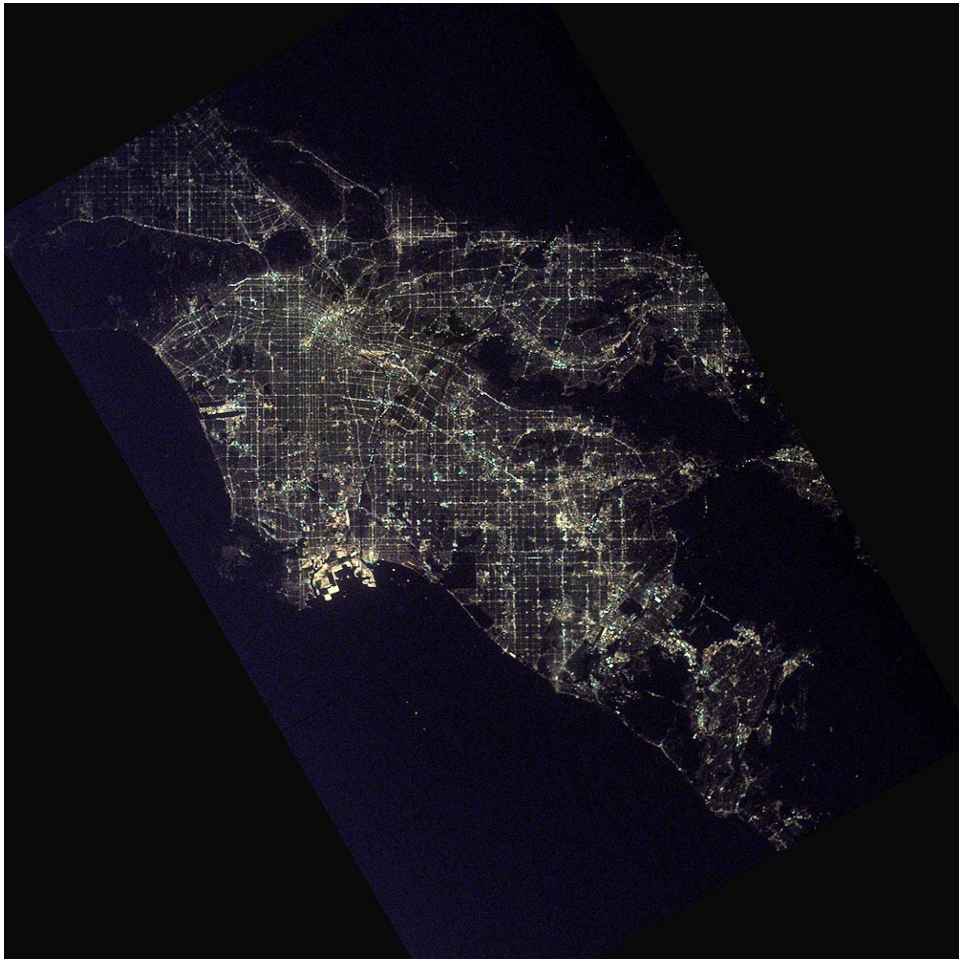
Eastern Egypt, the Red Sea, and Saudi Arabia, 4/29/90; NASA Photo ID: STS031-79-01, Film Type: 70mm.

Night Time - ISSS

Los Angeles at Night

After sunset the borders of “The City of Angels” are defined as much by its dark terrain features as by its well-lit grid of streets and freeways. Over 13 million people inhabit the coastal basin bounded roughly by the Santa Monica and San Gabriel Mountains to the north and the Chino Hills and Santa Ana Mountains to the east and southeast.

The crew (Petit) of the International Space Station took this unique image shortly after 1 a.m. local time on March 10, 2003. In the north, Hollywood is nestled against the south side of the Santa Monica Mountains. On the coast, Los Angeles International Airport (LAX) and the port facilities at Long Beach Naval Shipyards are bright spots. Finally, even at this time of night, the bright lights of Disneyland in Anaheim are a standout feature.



Earth Sciences and Image Analysis, NASA-Johnson Space Center. 9 Apr. 2003. "Astronaut Photography of Earth - Display Record." <http://eol.jsc.nasa.gov/scripts/sseop/photo.pl?mission=ISS006&roll=E&frame=36913&QueryResultsFile=1049975193544.tsv> (15 Apr. 2003).

Shuttle/Landsat

STS064-080-021
(STS064 launch September 9, 1994),

Landsat

The point here is to compare a film camera (Hasselblad with 250 mm lens, which is a 3x telephoto) to the standard earth resources satellite.

Systeme Probatoire d'Observation de la Terre

For many years, the SPOT satellites, with 10-meter spatial resolution for the pan-chromatic sensor, defined the high-resolution limit for remote sensing systems.

More recently, they improved the resolution of their system to 5-meters, with the launch of SPOT 5.

Note that by comparison to the Landsat image, the field of regard has been reduced.

SPOT – San Diego

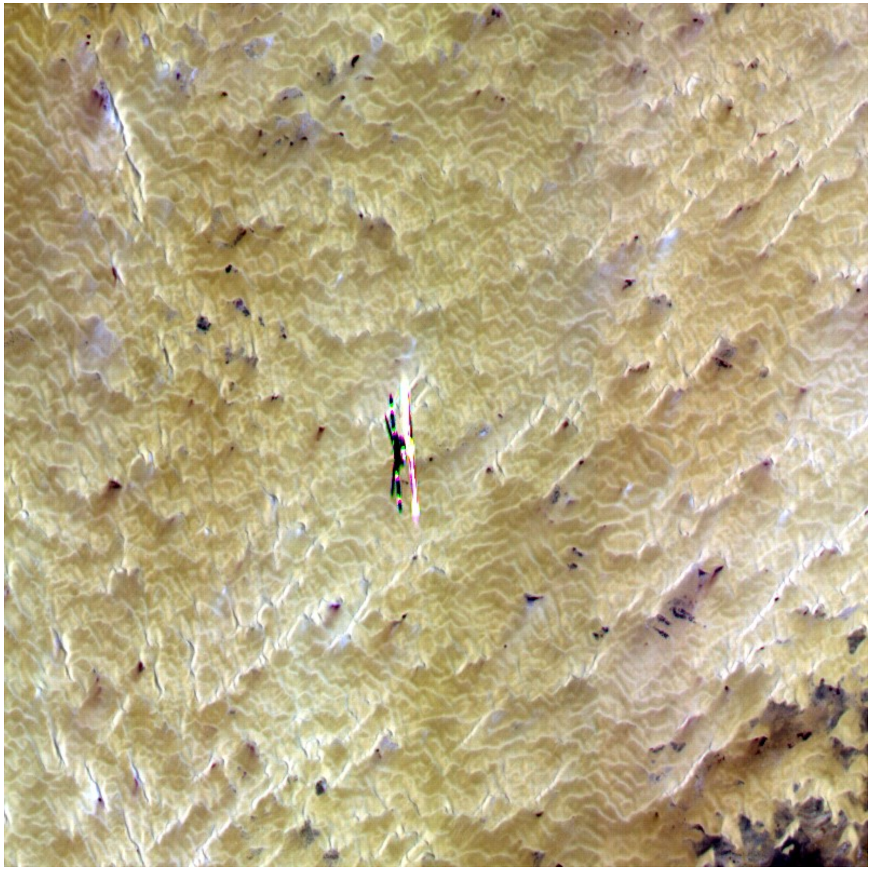
- **10-meter resolution through SPOT-4**

Sat²

Can one satellite take a picture of another satellite?

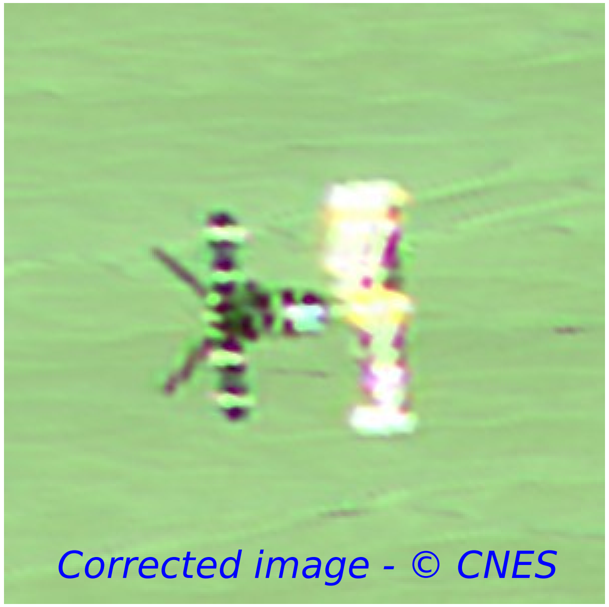
The Centre National d'Etudes Spatiales, CNES (French Space Agency) took a spectacular picture of the European ERS-1 satellite via SPOT 4, which was launched on 24 March 1998.

SPOT 4's orbit was determined using the facilities at the operations control centre for SPOT satellites at CNES/Toulouse, while the orbit for ERS-1 was determined by the ESA/ESOC/Darmstadt centre which controls it. The SPOT 4 telescopes, with their oblique viewing mirror, took this image above the Ténéré desert in Niger, on 6 May 1998 at 9:56 UT.



Sat² – SPOT views ERS-1

The ERS-1 orbit is 41 km below that of SPOT, which means that the latter can distinguish details of 50 cm in size on ERS-1. However, since ERS-1 flies much lower it flies faster than SPOT 4 and overtakes it with a relative velocity of about 250 km/h. These exceptional viewing conditions explain why the raw image (18 columns by 125 rows) is so distorted. Corrective processing was applied at CNES to restore the normal appearance of ERS-1.



ERS-1 is a radar observation satellite. On the right-hand side of the image may be seen the platform and the solar array, which are the same as SPOT's. On the left-hand side is the long, rectangular, synthetic aperture radar antenna of 10m x 1m, as well as two of the three scatterometer antennae used to measure wind fields. These two small antennae, inclined at 45°, are shorter and narrower (with dimensions of 3.6 m x 0.25m) than that of the radar, but stand out quite clearly in the image. The very bright areas in the image are due to the sun's rays bounced off the highly reflective outer layer which protects the satellite.

Just to show it was no fluke

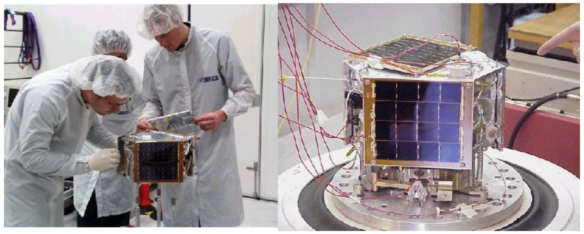
– **2 June 2002: SPOT5 views ERS2** *(See Notes)*

Raw image

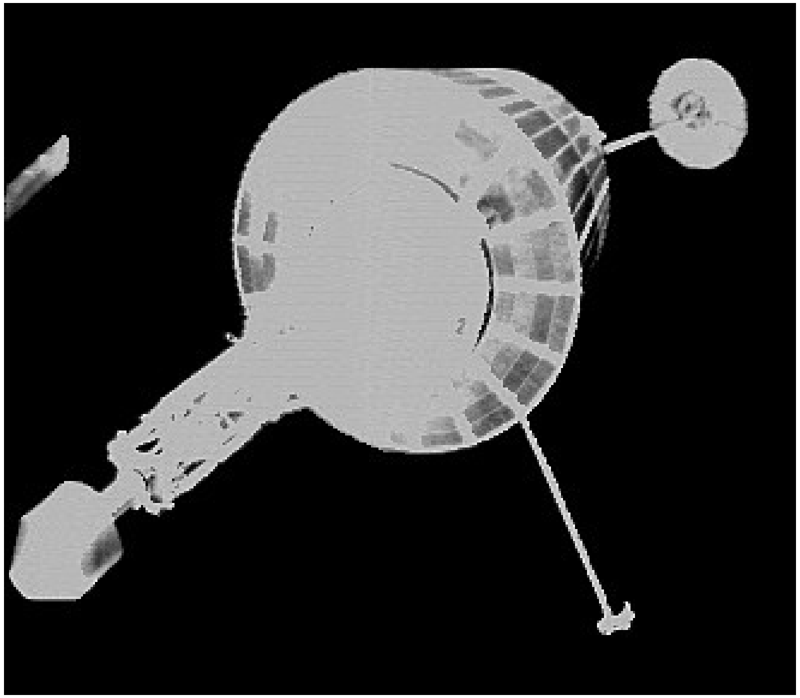
Processed image (12.5cm resampling)

UoSat – Sat²

SSTL SNAP-1 Nanosatellite



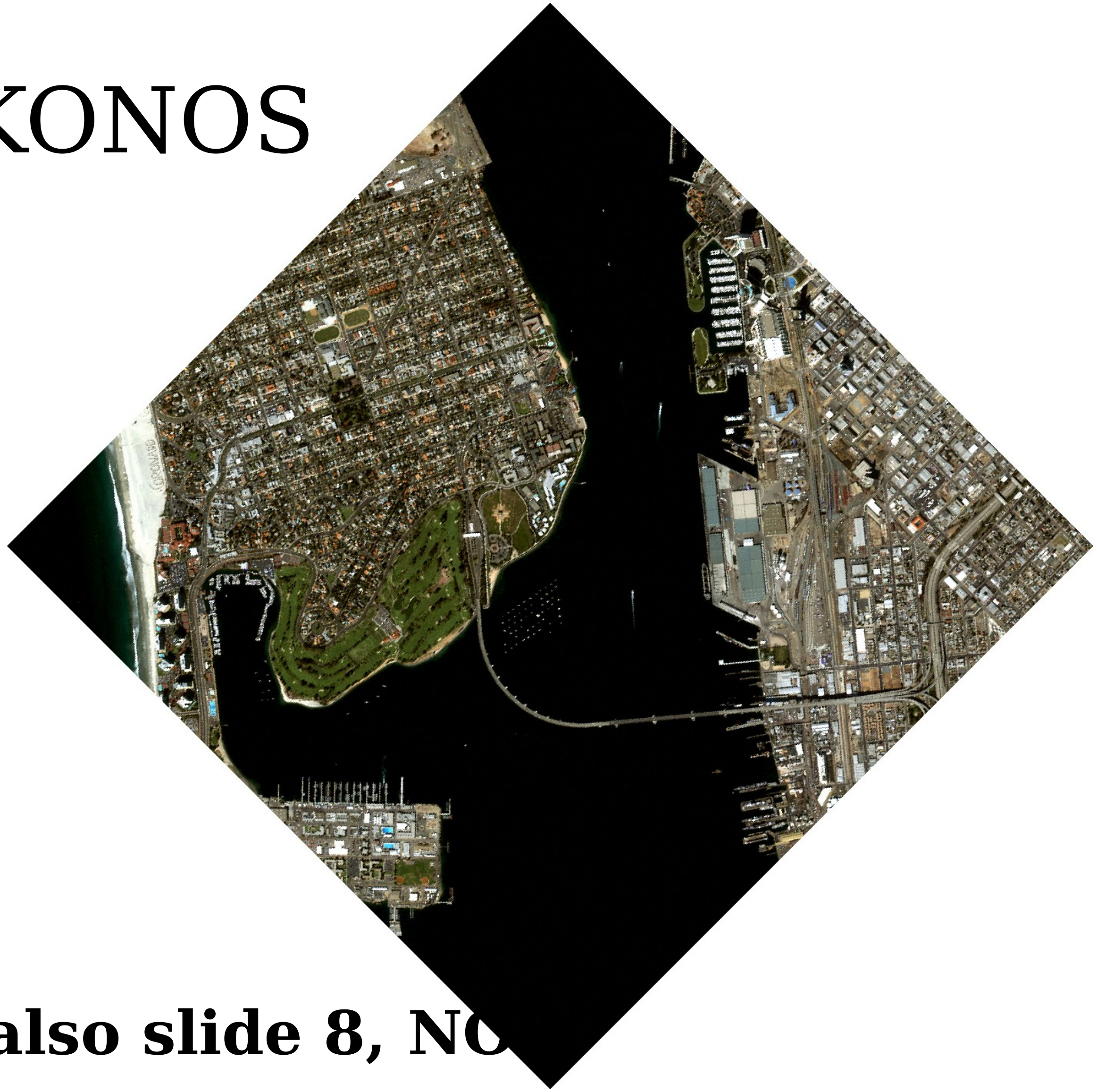
- In October 2000 the SNAP-1 nanosatellite used its innovative "machine vision system" of four micro-miniature single-chip video cameras (each smaller than a 2 pence/50 cent piece) to take images of other satellites as it flew past.
- The Russian Nadezhda COSPAS-SARSAT satellite imaged by SNAP-1 just 2 seconds after deployment when the spacecraft were approximately 2.2m apart.
  - October 23, 2000 Space News



IRS

- The country of India had the highest spatial resolution system on orbit for a few years in the late 1990's. IRS had 5-6 meter spatial resolution.
- Note that India was trying to make money from this system – they could not afford to build a Landsat-like system that would be supported by the government.
- Economics is starting to rule remote sensing

IKONOS



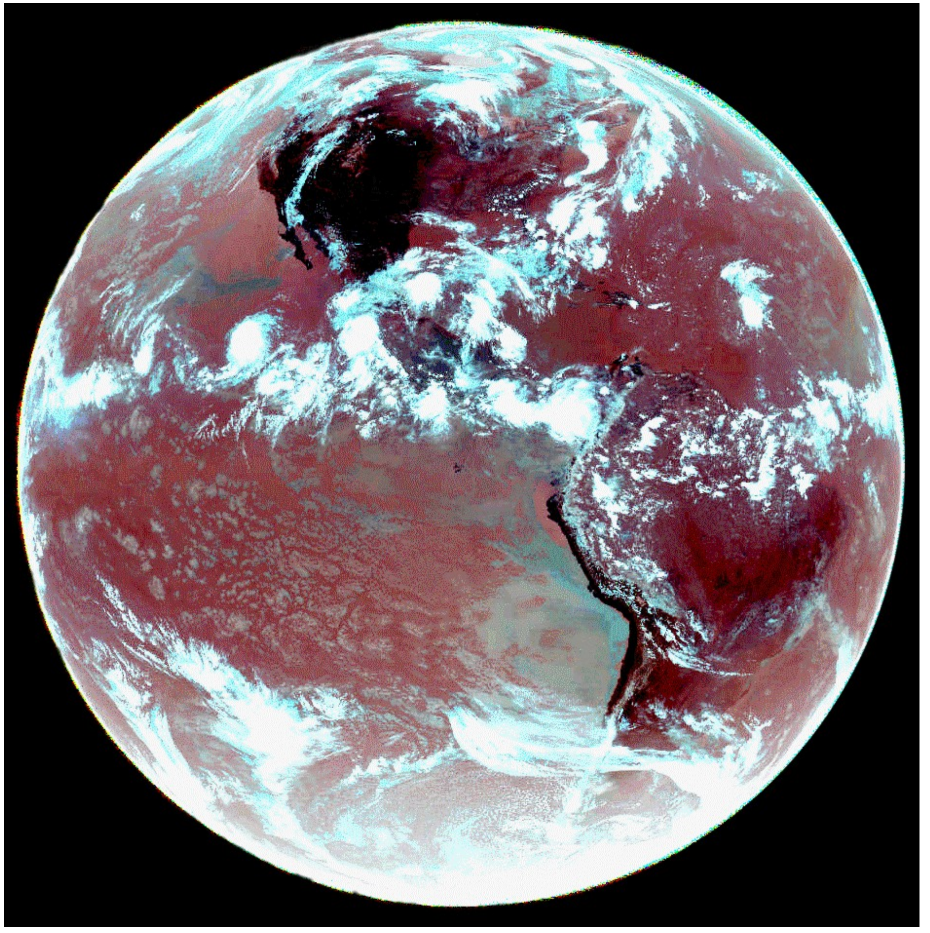
See also slide 8, NO

Airborne


RCI
CA-260/4 Imagery
SENSOR KS-87 E_O
LENS 12-inch fl
ALTITUDE 4,500 ft
SLANT RANGE 9,585 ft
SPEED 350 kn
LOCAL TIME 1330
PLATFORM ANG F-16

GOES – IR

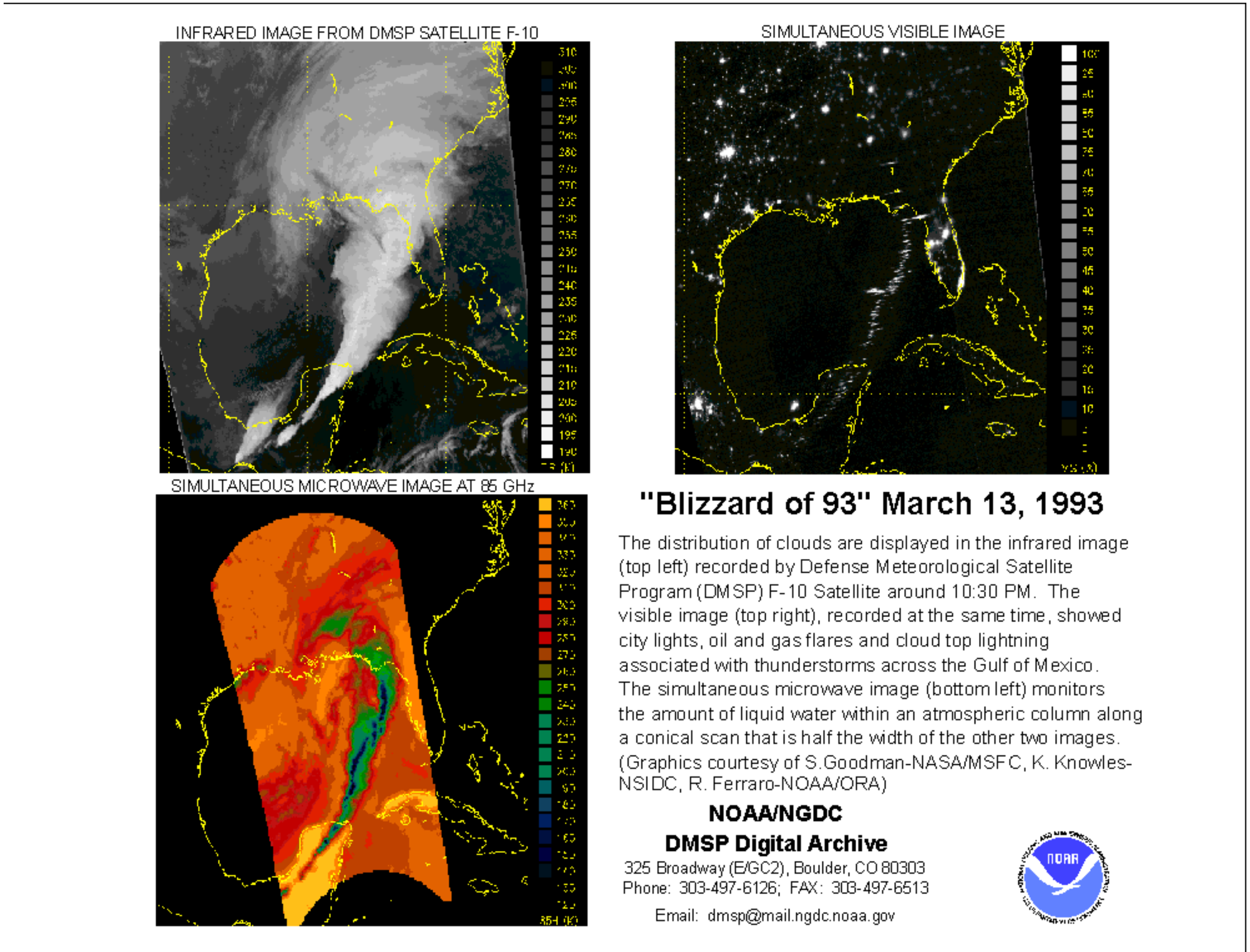
- 11 July 1995, 1800 UTC
- Wavelength bands: 3.9, 11, and 12 microns encoded as red, green, and blue
- Note that a popular error, of sorts, is propagated here – cold is white, hot is black.



Landsat - IR

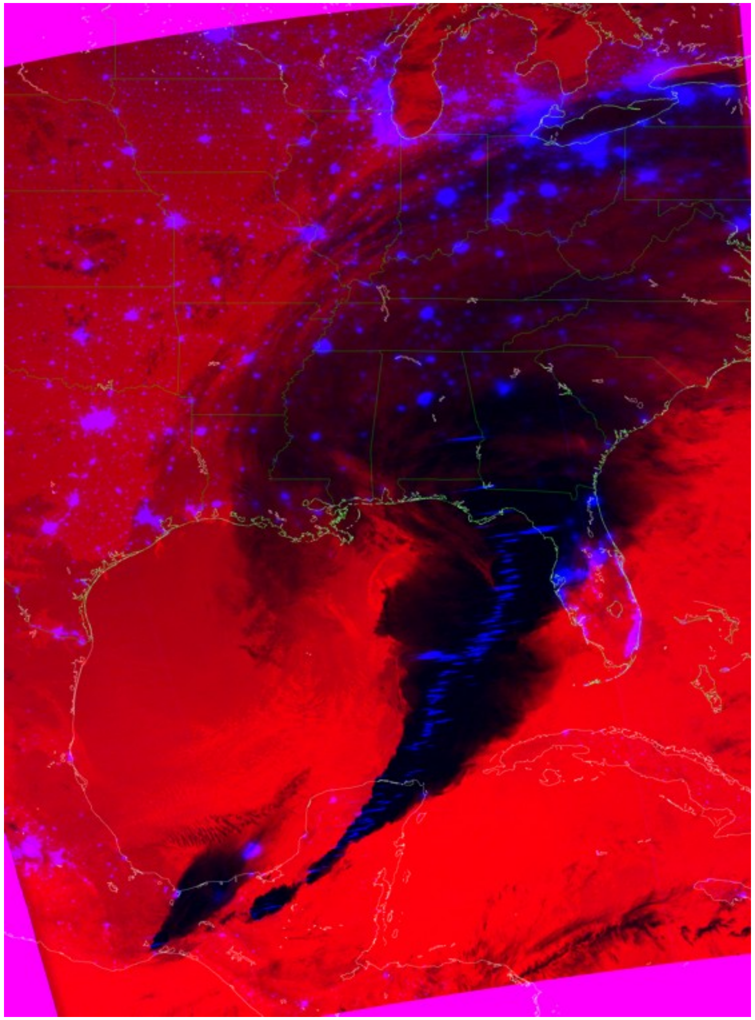
Landsat - IR San Diego - 7 May 1996 (bands 6, 5 and 7)

DMSP – MMW and IR

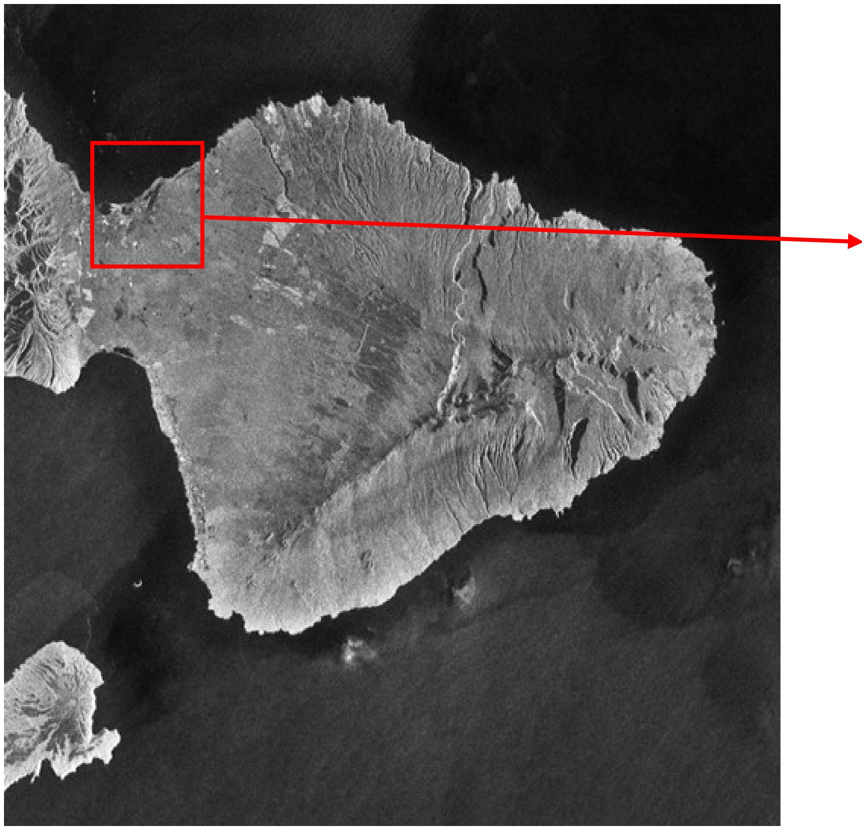


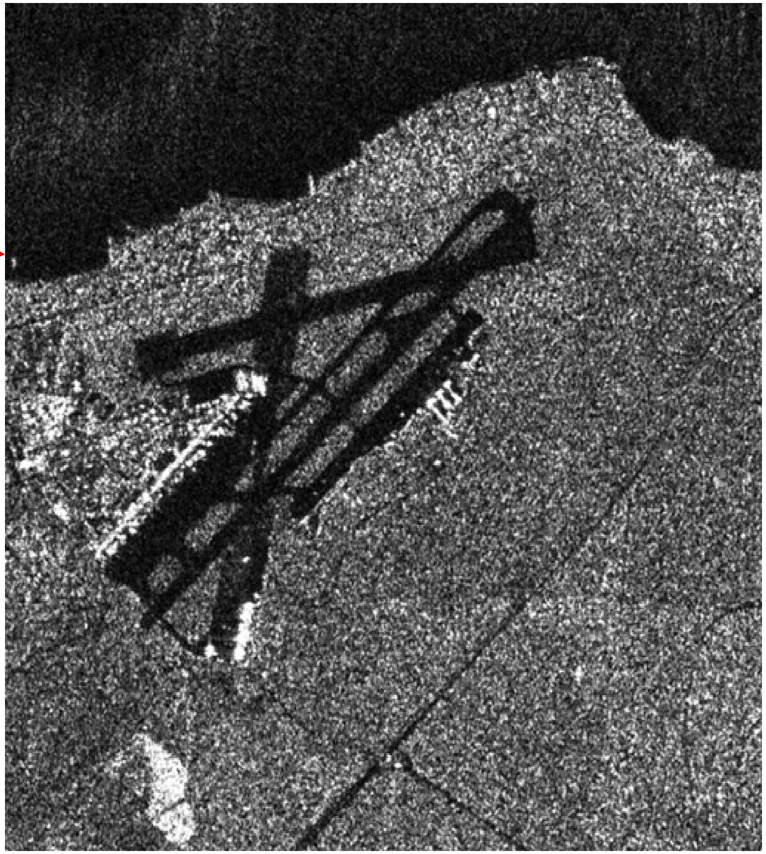
DMSP – Visible and IR

Combining the imagery from the two sensors, we see lightning, city lights, and clouds

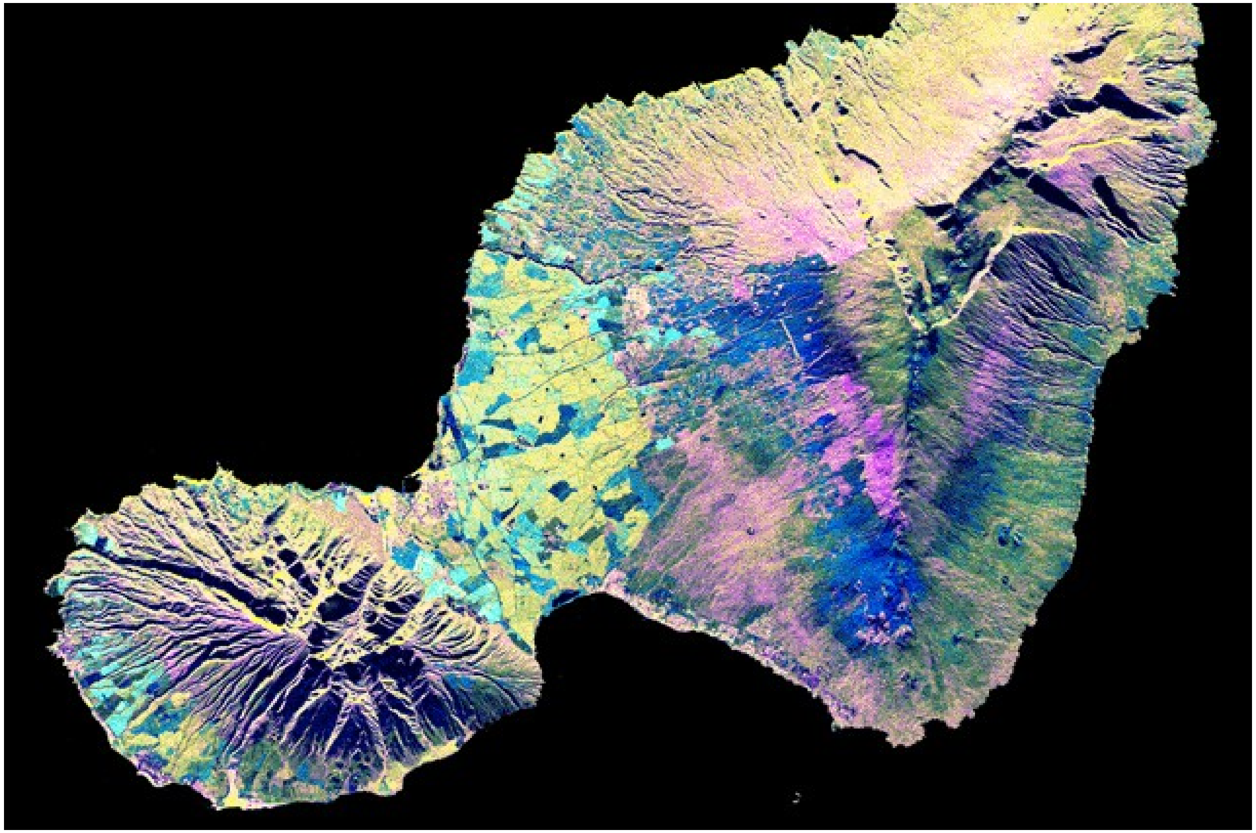


Radarsat - Maui



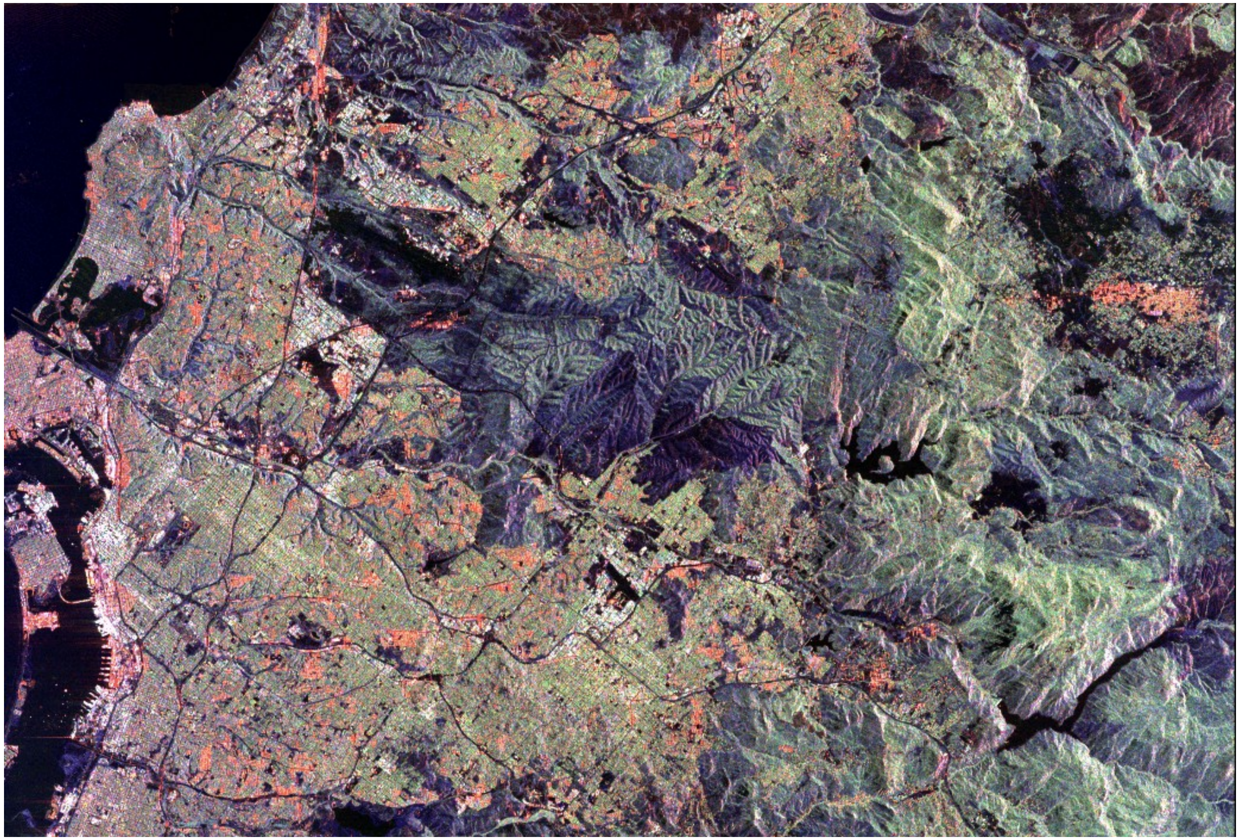


SIR-C Maui



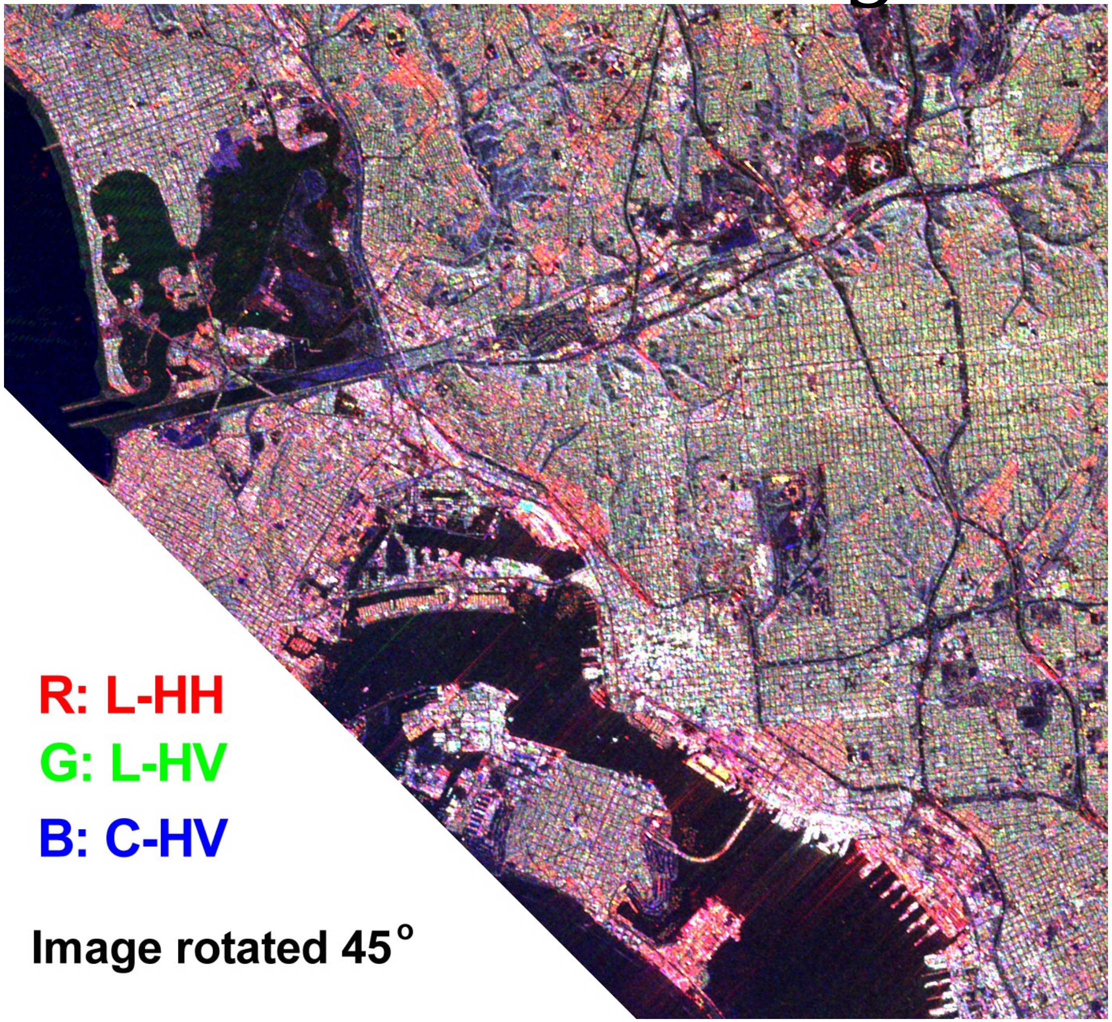
Space Shuttle Endeavor, April 16, 1994
red is L-band, horizontally transmitted and received;
green is C-band, horizontally transmitted and received; and
blue is the difference of the C-band and L-band channels.

SIRC – San Diego



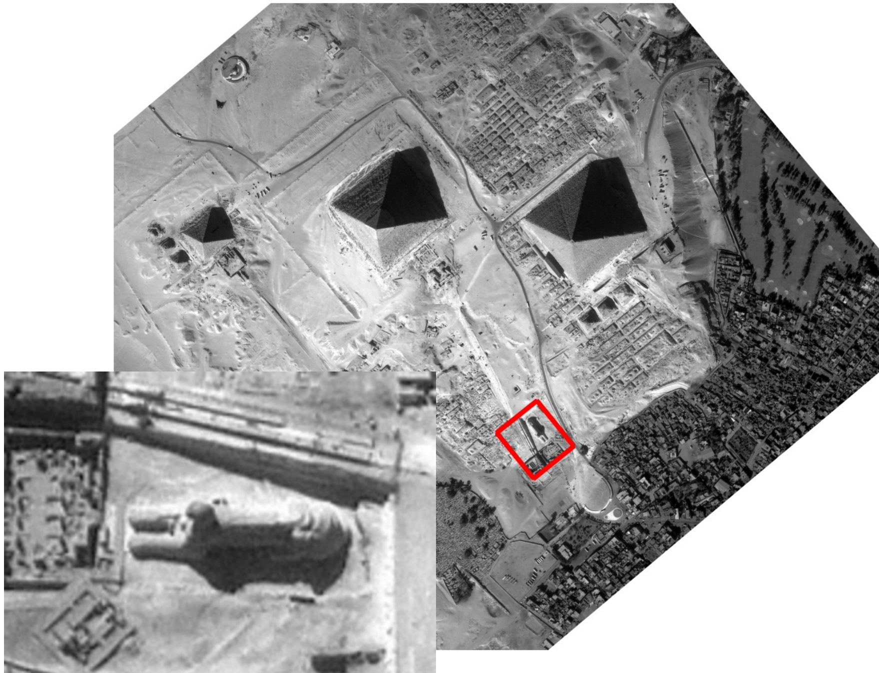
October 3, 1994

SIRC – San Diego

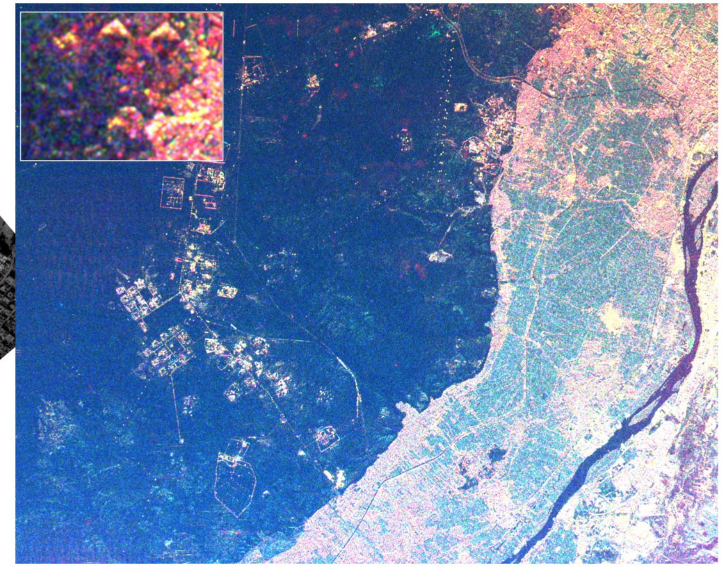


October 3, 1994

The Great Pyramids of Giza, Egypt



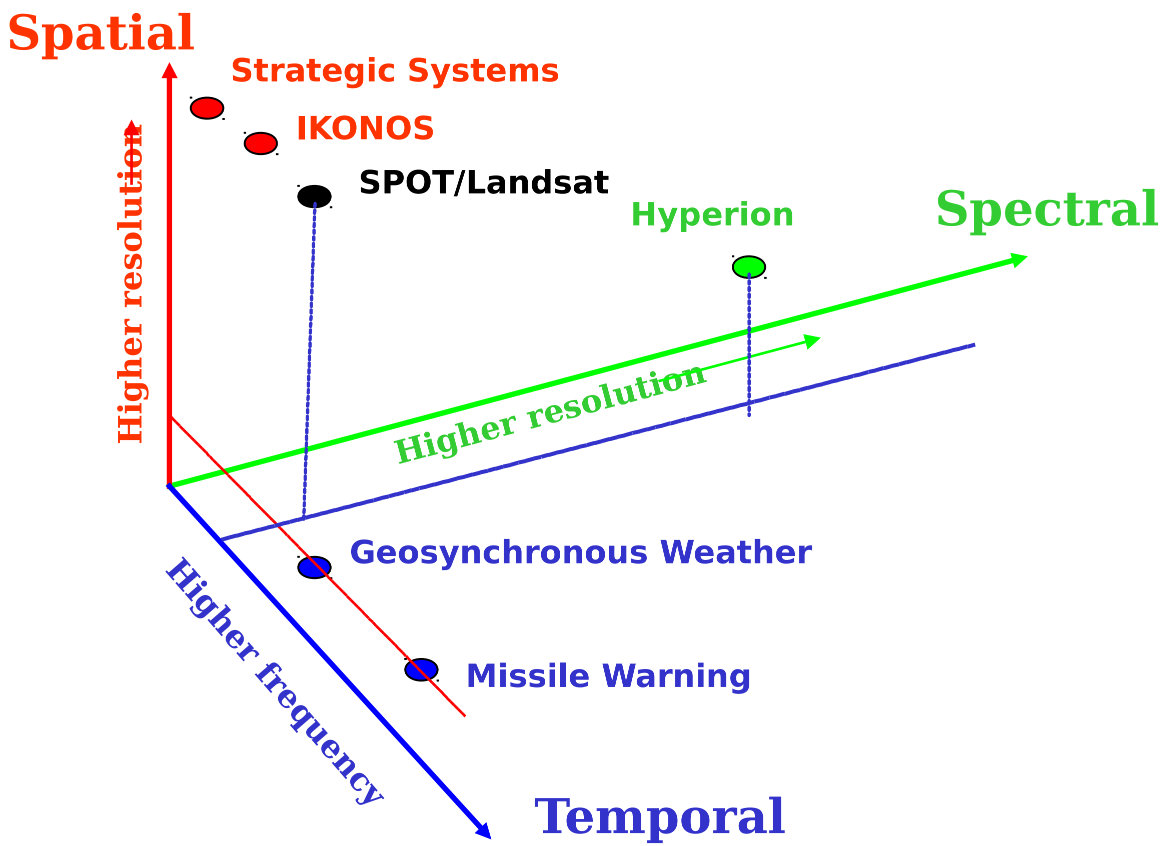
IKONOS – November 11, 1999
1-meter resolution image of the Great Pyramids and Sphinz at Giza, Egypt. The largest pyramid, built by Cheops (Khufu) in 2500 BC, stands in the center. They pyramid built by Mycerinus in 2530 BC is to the right, while the smaller pyramid built by Chephren in 2570 BC is to the left. The Sphinx, built in about 2540 BC, is boxed in red, and then shown enlarged. The image was rotated 130° to match the orientation of the radar image.



This SIR-C/X-SAR radar image was acquired on 19 Apr 94 shows the area west of the Nile River near Cairo, Egypt. The Nile River is the dark band along the right side of the image and flows approximately due North from the bottom to the right. The boundary between dense urbanization and the desert can be clearly seen between the bright and dark areas in the center of the image. This boundary represents the approximate extent of yearly Nile flooding which played an important part in determining where people lived in ancient Egypt. This land usage pattern persists to this day. The pyramids at Giza appear as three bright triangles aligned with the image top just at the boundary of the urbanized area. They are also shown enlarged in the inset box in the top left of the image.

(See Notes)

Three Axes

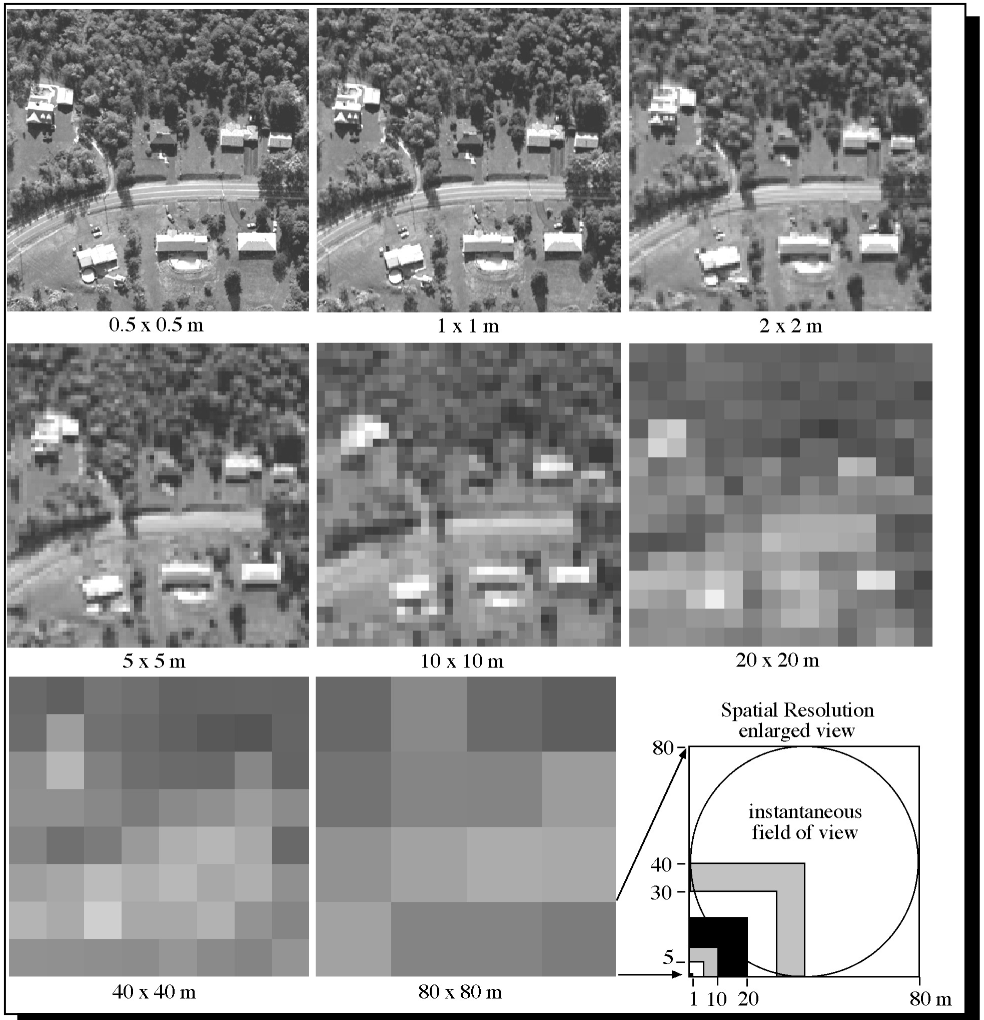


Spatial
Spectral
Temporal

Describing Sensors

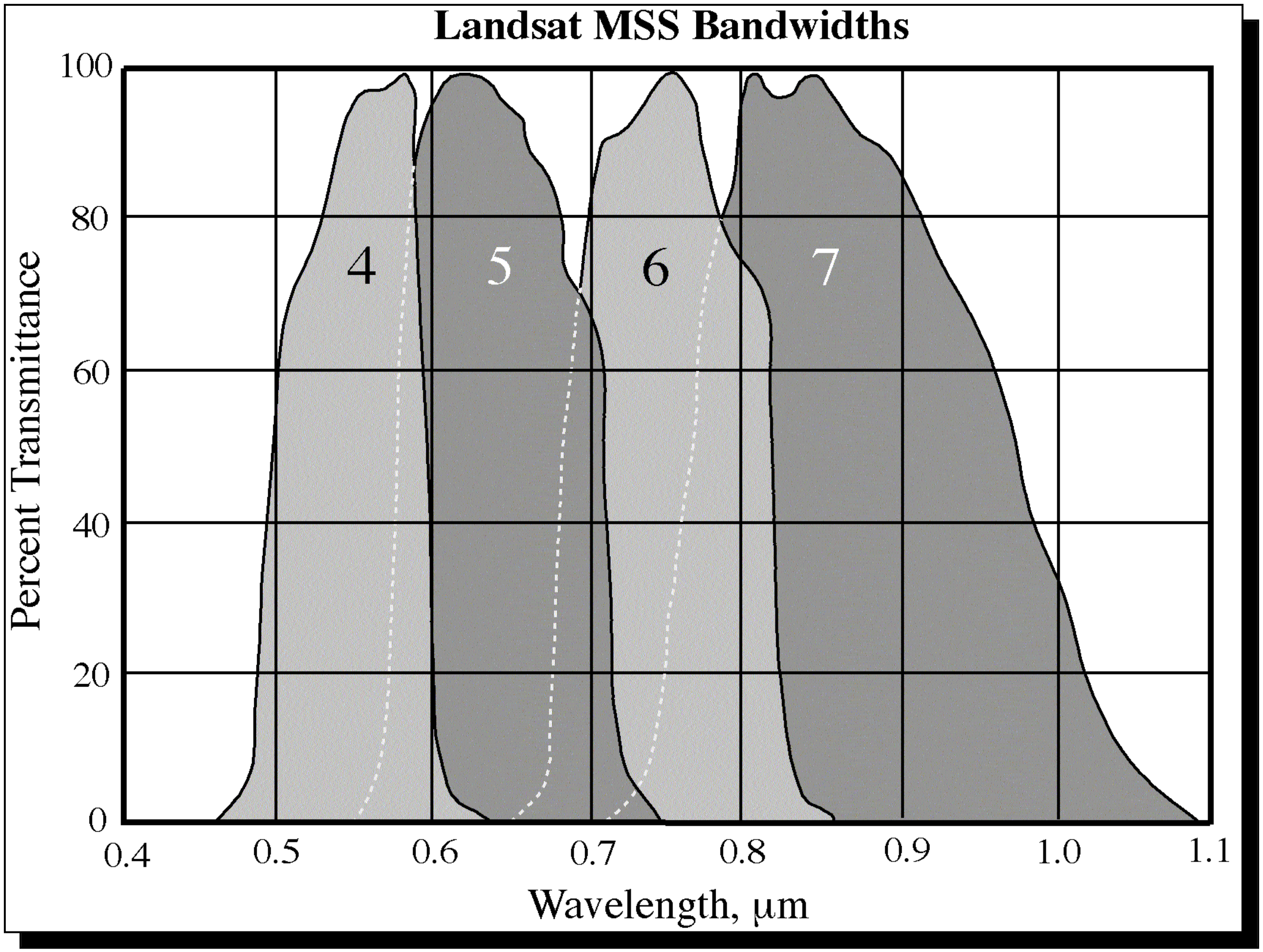
- **Resolution**: the smallest difference between two units of measurement that is resolvable by a sensor
- **Extent**: the range of units of measurement that a sensor can resolve

Spatial Resolution



General rule of thumb: the spatial resolution should be less than half of the size of the smallest object of interest.

Spectral Resolution



MSS has 4 spectral bands:

- Band 1: 0.5 to 0.6 μm (green)
- Band 2: 0.6 to 0.7 μm (red)
- Band 3: 0.7 to 0.8 μm (near IR)
- Band 4: 0.8 to 1.1 μm (near IR)

Radiometric Resolution

1-bit
2 greys

her Olsen

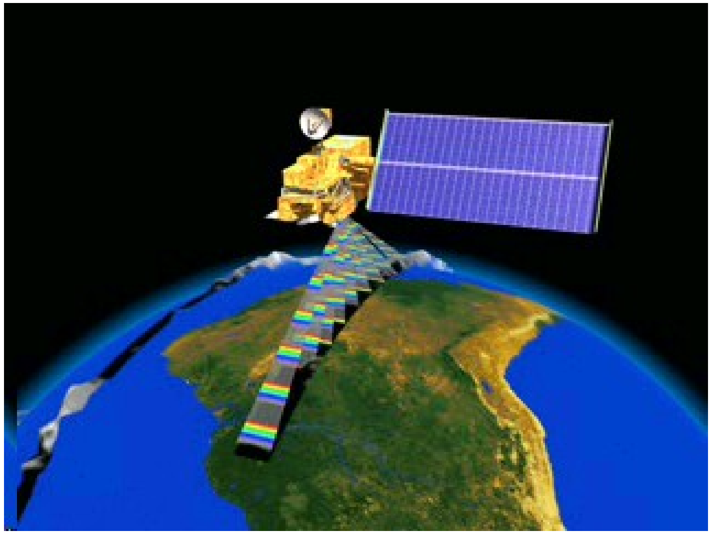
Radiometric Extent

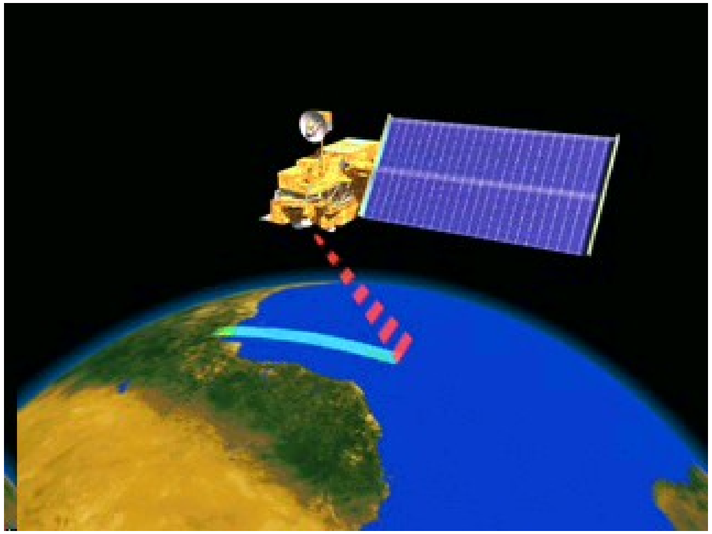
Maximum brightness = 127

her Olson

Temporal Resolution

MISR and MODIS are both on the TERRA satellite:

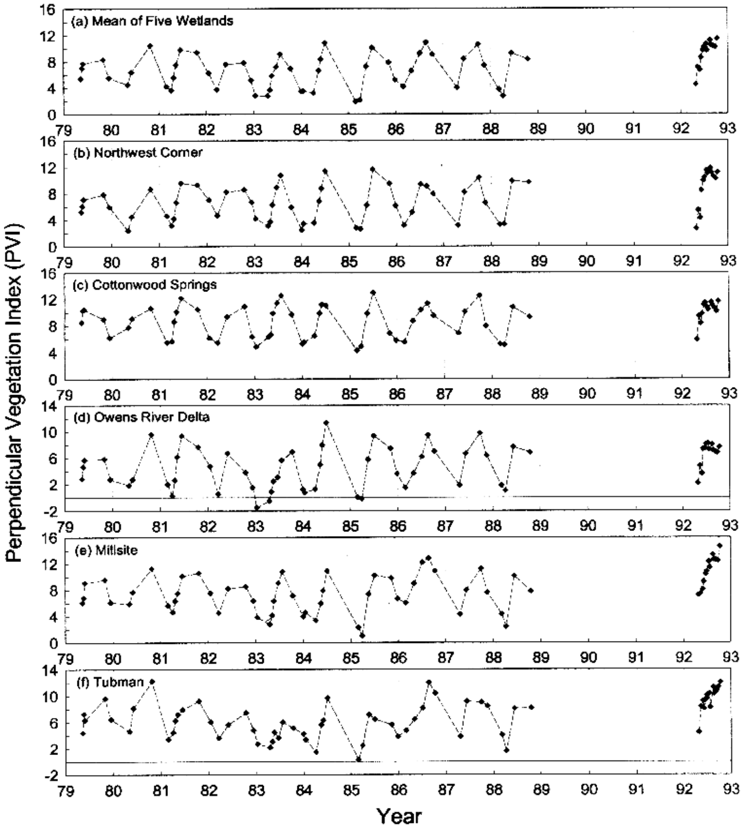




MISR has a swath width of 360 km. and images the earth once every 9 days. Can play on: http://terra.nasa.gov/About/MISR/misr_swath.html

MODIS has a swath width of 2,330 km. and images the earth once every 1 to 2 days. Can play on : http://terra.nasa.gov/About/MODIS/modis_swath.html

Time Series Analysis



- Elvidge et al. 1998 – study of vegetation indices in Landsat data.
- Used 64 (!) MSS images in time series analysis
- Elvidge fit a sine function to the data to determine cycling (yearly) and then determined long term trends.
- Note: there are powerful algorithms for describing time series data, but RS’ers don’t use them!